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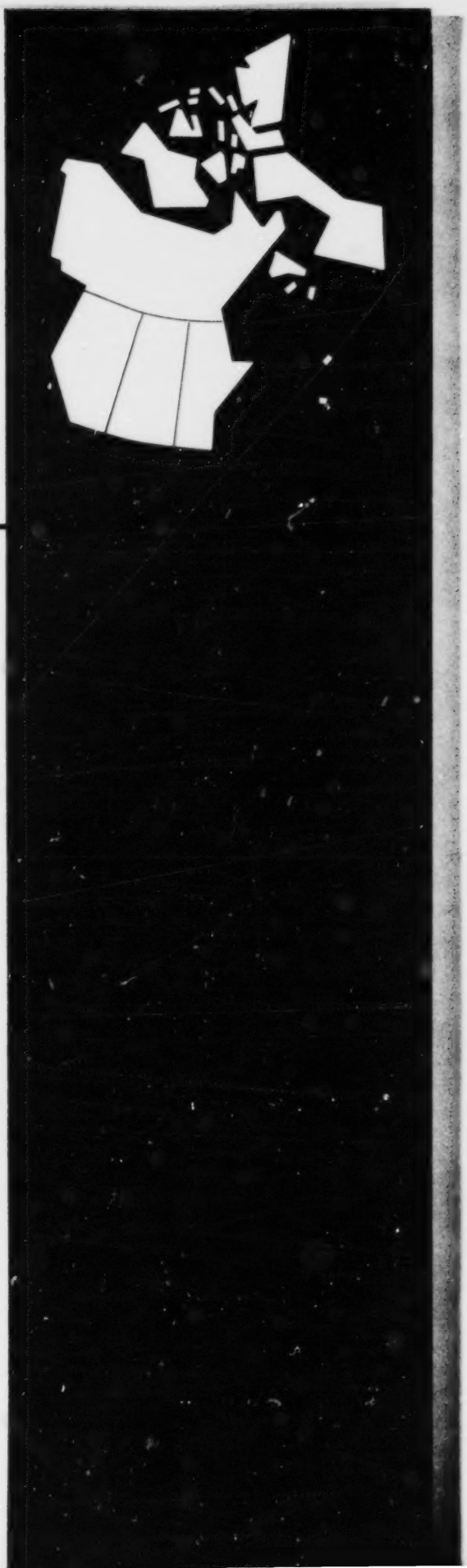

THE ENVIRONMENTAL EFFECTS OF CANADIAN WATER DIVERSIONS; A LITERATURE SURVEY

R. N. NEUMEYER

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ENVIRONMENT CANADA
WATER PLANNING AND MANAGEMENT BRANCH
WESTERN AND NORTHERN REGION
REGINA, Saskatchewan

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THE ENVIRONMENTAL EFFECTS OF CANADIAN WATER DIVERSION:

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ABSTRACT

The report describes the methodology and results of a 1985 literature survey. The survey was undertaken to locate and identify available literature on the environmental effects of existing Canadian water diversion projects. Information was located by searching several computerized data bases and by soliciting appropriate private sector, academic and government agencies. A description of the data bases and a list of respondants is included in the body of the report. A total of sixty-one documents were selected. The report also provides location maps, diagramatic plans, reference citations, design details and major environmental effects or concerns for eleven (11) diversion schemes. Comprehensive annotations are provided for each reference.

The body of published literature on this subject was found to be suprisingly limited with the number of predictive (impact assessment) publications far exceeding the number addressing actual ecological consequences of completed projects. Therefore, references associated with four (4) proposed projects are included to serve as examples of predictive assessments.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the contribution made to this survey by Mr. Kam Naik. Mr. Naik carried out the computer search and agency solicitation phase of the survey. The material collected by Mr. Naik formed the basis of this report.

The following members of the Water Planning and Management Branch, Environment Canada, Regina, have also contributed to this report. Mr. G. Babish provided report layout and graphics, Mr. E. Smith assisted in the computer search, Mr. J. Rogers prepared tables 1, 2 and 3 and Mrs. S. Campbell typed the report and provided valuable editorial assistance.

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1.0 INTRODUCTION

Geographic and seasonal reallocation of surface water is common practice in Canada. In 1980, the total volume of Canadian water diversions was much greater than the next two leading countries, the United States and the Soviet Union. At that time our combined annual diversion flow (1980) would have constituted the third largest "river" in Canada, exceeded in size only by the Mackenzie and St. Lawrence rivers (52). However, it appears that by the year 2000, around 20 cubic kilometers (km^3) of water per year will be diverted southward from the northern regions of the USSR, and that facilities to transfer 27 km^3 from western Siberia into Kasakhstan and Central Asia will be under construction (44 a).

Canada is fortunate, perhaps, that its geography favours water transfer. Except for the mountainous areas of the west, basin divides are generally not formidable. Many examples of lakes that drain in two directions and of rivers that change their course during flood may be found.

In the past, the primary justification for water transfer projects has been the need to maximize hydroelectric power production. In Canada, hydro-electric projects utilize about 95% of the total water transfer, and are dominant both in number and scale. The remainder are associated with large open pit mines, such as the Syncrude operation near Fort McMurray, Alberta or with crop irrigation and municipal water supply systems (27, 38, 48 and 52).

Redirecting water from one river into another alters the hydrologic characteristics of receiver and donor basins. The situation is outlined in the following quote from Bodaly et al (21);

> "Under natural conditions, the potential energy of a river is expended by fluvial processes that carve and transport sediment from a myriad of channels that combine to form a river system. At any point in the system, the size and form of the river channel reflect the quantity of water conducted, the geological materials of the basin and the length of time that this particular combination of water and land has been in existence. The balance between the creation of land masses through crustal movements and the removal of the land surface by river erosion occurs over geological epochs that far exceed the record of man's observations. This natural rate of evolution is in strong contrast to the nearly instant change of diverting a river or flooding a lake. Such rates of rapid change are observed only during earthquakes or other catastrophic events and even these are seldom on the basin-wide scale of a river diversion. The rapid adjustment of a hydraulic regime is not followed by a rapid establishment of new stable values of other characteristics of the ecosystem. Instead, changes in the environment take place as natural forces which act on a geological time scale change the

> nature of their influence in the environment. ... The evolution of aquatic systems after river diversion and impoundment is not towards the original state before development, but rather towards a new state, the form of which depends on the nature of the water flow and water level manipulations. ..."

Biological communities that have developed in prediversion riverine environments need to make some rather fundamental adjustments. The more drastic the change in river regime, the more extensive will be the alterations in original community structure. Shifts in the composition of biological communities can translate into real economic hardships, exemplified by the post-diversion mercury contamination of important fish stocks in the lower Churchill-Nelson system (Manitoba) or the reduction of the subsistence fishery in the La Grande River (Quebec).

Although a variety of mitigative measures may be incorporated into the design of a large diversion scheme, in general, basic alterations within resident ecosystems cannot be prevented. A diversion of flow may cause relatively significant biological impacts (both positive and negative). Therefore, it is important that management fully appreciate the magnitude, nature and duration of these effects.

Over the years the Western and Northern Regional office of the Inland Waters Directorate, Environment Canada has spent considerable time evaluating both large and small scale diversion projects. Tables 1, 2 and 3, extracted from the 1985 Water Planning and Management Branch inventory of existing water transfers in the Prairie Provinces (13b), demonstrate the regional importance of this engineered solution to water supply problems. Ecological questions were often raised but definitive answers were seldom, if ever, on hand. The extensive Canadian water diversion activity suggested that the published literature should contain valuable insights on the ecological implications of such projects. Therefore the office initiated a literature survey on this topic.

The primary purpose of the survey was to determine the extent and nature of the published literature dealing with the ecological effects of existing Canadian water diversions. Consequently, information on diversion projects external to Canada, such as the Garrison Development, has not been included nor have economic or social implications been addressed. Biological rather than hydraulic, hydrologic or physiographic effects have been emphasized. (For information on these latter aspects see 26, 27, 33, 38 and 39). Also the frequently used phrase "interbasin" has been more narrowly defined (section 2.3 c.) then appears to be the case in general publications. By this definition most Canadian water diversions are, in fact, intrabasin, which implies less dramatic ecological consequences.

It is intended that this report provide a "springboard" for those planning to undertake further work in this important area.

2.0 METHODOLOGY

In this section search methodology is described. This will allow the reader to decide if the survey has missed important sources of information.

2.1 Computer search

A computer search for bibliographic references is only possible if this information has been entered onto machine-readable files, typically magnetic discs. A computer program is then able to compare information (a request) entered by the user with the data stored on a machine-readable file or data base. Whenever a match occurs a user is informed and may elect to view the stored information on that reference. Keywords are employed to facilitate the matching process. In this survey, data bases, maintained by Quicklaw Systems (Water Documents - WATDOC) and Canadian Online Enquiry (National Research Council), were accessed (section 6.1).

An extensive group of keywords were used to ensure a high success of capture. Derivation of these required a combination of professional judgment and trial and error. The words finally selected were:

biolog*
diversion*
effect*
ecolog*
ecosystem
environment*
interbasin
impact
lake(s)
intrabasin
organism*
river
transfer(s)
water
hydro
hydroelectric
dams

(* denotes truncation. Many words may be generated from the root, e.g. biolog* could generate biology, biological, biologic, etc.)

Potentially relevant reports on the Quicklaw (QL) system were retrieved using a form letter and postage-paid response card (Figure 4) forwarded to the originating author or agency (Appendix 6.2). Hard copy of the CAN/OLE references were obtained directly from the Canadian Institute for Scientific and Technical Information (CISTI), through interlibrary loans. The preliminary screening of references involved two basic "steps". First, the document had to pertain to existing Canadian water diversions. Second, the ecological (environmental) implications had to be addressed. However, references addressing proposed Canadian water transfers were not discarded (Figure 1). A general reference file was established for these. As it turned out the references to existing projects were so limited that these more conceptual documents have been acknowledged in the review. Certain of these proposed diversion schemes were selected for inclusion in order to illustrate the general nature of predicted impacts.

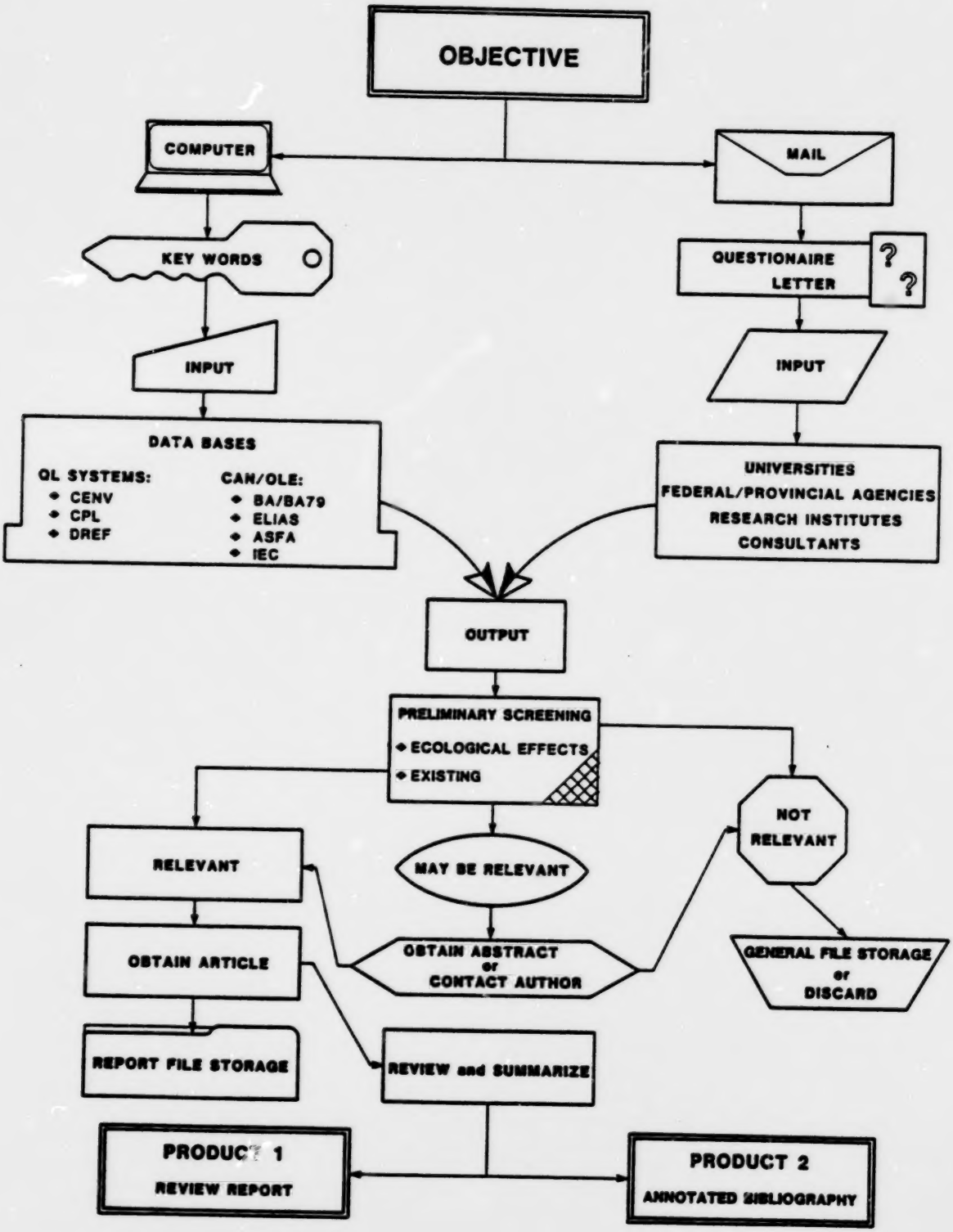


Figure 1: Flow Chart of Survey Process

Table 1: Alberta Water Diversions

ALBERTA WATER TRANSFERS

Project No. and Name	Contributing Waterbody, Basin	Receiving Waterbody, Basin	Average Annual Transfer (or Capacity)	Purpose(s)	Date Operational (Original date if reconstructed)	Owner
1. Beaver Creek Diversion	Beaver Creek, Athabasca River Basin 56°59'N, 111°40'W	Poplar Creek, Athabasca River Basin 56°52'N, 111°39'W	1.9 m^3/s	Mining	1976	Syncrude Canada Limited
2. Bow River Irrigation District	Bow River at Carseland South Sask. Basin 50°50'N, 113°27'W	MacGregor Reservoir, Little Bow River Basin Oldman	8.6 m^3/s	Irrigation	(1920) 1958	Alberta Government
(a) Little Bow* Canal	Highwood River at High River Bow River Basin 50°35'N, 113°53'W	Little Bow River, Oldman Basin 50°35'N, 113°50'W	0.4 m^3/s	Irrigation	1910	Alberta Government
3. Eastern Irrigation District	Bow River, South Sask. Basin 50°45'N, 112°32'W	Bow and Red Deer Rivers South Sask. Basin 50-51°N, 111-112°W	19.2 m^3/s	Irrigation	1914	Eastern Irrigation District
4. Western Irrigation District	Bow River, South Sask. Basin 51°03'N, 114°01'W	Chestermere Lake, Bow and Red Deer Basins 51°15'N, 113-114°W	4.3 m^3/s	Irrigation	1910	Alberta Government
5. Lethbridge Northern Irrigation District	Oldman River South Sask. Basin 49°40'N, 113°36'W	Keho Lake Oldman Basin 50°N, 112°30'W	4.8 m^3/s	Irrigation	1924	Alberta Government
6. Mountain View-Leavitt-Aetna Irrigation Canal	Belly River, Oldman River Basin 49°06'N, 113°42'W	St. Mary River, Oldman River Basin 49°12'N, 113°15'W	0.4 m^3/s	Irrigation	(1936), 1949	Alberta Government
7. Waterton-Belly -St. Mary Transfer	Waterton, Belly and St. Mary Rivers, Oldman River Basin 49°22'N, 113°07'W	Oldman and South Sask., South Sask. Basin 49-50°N, 111-113°W	14.0 m^3/s	Irrigation	(1890s) 1969	Alberta Government
(a) Belly-St. Mary* Diversion	Waterton & Belly Rivers, Oldman, South Sask. 49°20'N, 113°33'W	St. Mary Reservoir Oldman, South Sask. 49°22'N, 113°07'W	2.0 m^3/s	Irrigation	1959	Alberta Government
(b) Waterton-* Belly Diversion	Waterton Reservoir, Oldman River Basin 49°20'N, 113°40'W	Belly River, Oldman River Basin 49°20'N, 113°33'W	3.5 m^3/s	Irrigation	1968	Alberta Government
(c) St. Mary* Diversion	Waterton, Belly and St. Mary Rivers Oldman Basin 49°22'N, 113°07'W	Jensen Reservoir Oldman Basin 49°20', 112°54'W	8.6 m^3/s	Irrigation	(1890s) 1969	Alberta Government
8. Brazeau Power Canal	Brazeau River, North Sask. Basin 52°58'N, 115°36'W	Brazeau River, North Sask. Basin 52°54'N, 115°23'W	52 m^3/s	Power	1965	Calgary Power Ltd.
9. Ghost to Minnewanka Lake Diversion	Ghost River, Bow River Basin 51°18'N, 115°10'W	Lake Minnewanka, Cascade, Bow Basin 51°15'N, 115°17'W	1.4 m^3/s	Power	1941	Calgary Power Ltd.
10. Spray River Hydro Transfers	Spray and Kananaskis Rivers, Bow River Basin 50°54'N, 115°22'W	Bow River, South Sask. Basin 51°05'N, 115°22'W	12 m^3/s	Power	1949-1959	Calgary Power Ltd.
(a) Smith-Dorrien* Diversion	Smith-Dorrien Creek, Kananaskis, Bow Basins 50°47'N, 115°18'W	Spray River, Bow River Basin 50°48'N, 115°19'W	.75 m^3/s	Power	1949	Calgary Power Ltd.
11. Ross Creek Irrigation District	Gros Ventre Creek, Ross Creek South Sask. River Basin, 49°53'N, 110°29'W	Cavan Lake, Ross Creek South Sask. Basin 49°55'N, 110°24'W	0.4 m^3/s	Irrigation	1950	Ross Creek Irrigation District
12. Squaw Coulee Diversion	Highwood River above High River Bow Basin 50°33'N, 113°59'W	Mosquito Creek Little Bow River Old Man Basin 50°33'N, 133°58'W	0.2 m^3/s	Irrigation Stock Watering	1949	Alberta Government

* Subsystem diversion volumes are incorporated in system totals, immediately preceding.

Table 2: Saskatchewan Water Diversion

SASKATCHEWAN WATER TRANSFERS

Project No. and Name	Contributing Waterbody, Basin	Receiving Waterbody, Basin	Average Annual Transfer Flow (or Capacity)	Purpose(s)	Date Operational	Owner
1. Cypress Lake Diversions	Belanger & Davis Creeks (Frenchman River) and Battle Creek 49°30'N, 109°30'W	Cypress Lake, Frenchman River and Battle Creek 49°30'N, 109°30'W	0.6 m^3/s	Irrigation	1939	PFRA, Gov't of Canada
2. Qu'Appelle Diversion	Lake Diefenbaker South Saskatchewan Basin 50°58'N, 106°26'W	Qu'Appelle River Assiniboine Basin 50°45'N, 105°40'W	1.5 m^3/s	Multiple (munic., recreation, irrigation)	(1959) 1967	Government of Saskatchewan
3. Saskatoon Southeast Water Supply System	Lake Diefenbaker South Saskatchewan Basin 51°16'N, 106°37'W	Little Manitou Lake and other reservoirs en route 50°45'N, 105°39'W	1.6 m^3/s	Multiple (munic., indus., irrig., wildlife, rec.)	1968	Saskatchewan Water Corporation
4. Eldorado Nuclear Ltd. Hydroelectric Projects	Tazin Lake Talston Basin 59°40'N, 108°45'W	Charlot River Lake Athabasca-Slave Basin 59°35'N, 109°10'W	30 m^3/s	Hydropower	1958	Eldorado Nuclear Ltd.
5. Cumberland Marshes Project	Saskatchewan River 53°48'N, 102°58'W	Birch River/ Saskatchewan River Saskatchewan River Basin 53°50'N, 103°56'W	2.2 m^3/s	Wildlife	Various	Gov't of Saskatchewan/ Ducks Unlimited is the operator
6. Swift Current Irrigation Project, Rush Lake Project	Swift Current Creek S. Sask. Basin 50°16'N, 107°46'W	Rush Lake, Old Wives Lake Basin 50°25'N, 107°20'W	0.51 m^3/s	Irrigation	1953	PFRA, Gov't of Canada

Table 3: Manitoba Water Diversion

MANITOBA WATER TRANSFERS

Project No. and Name	Contributing Waterbody, Basin	Receiving Waterbody, Basin	Average Annual Transfer (or Capacity) in m^3/s	Purpose(s)	Date Operational	Owner
1. Churchill River Diversion	Southern Indian Lake Churchill River Basin 56°40'N, 98°55'W	Rat-Burntwood Rivers Rivers Nelson River Basin 56°40'N, 99°04'W	760 m^3/s	Hydropower	1976	Manitoba Hydro
2. Pine Creek Diversion	Pine Creek Roseau River Basin 49°08'N, 95°54'W	Roseau Wildlife Management Pools (US) Roseau River Basin 48°56'N, 96°15'W	0.75 m^3/s	Wildlife	1953	Province of Manitoba
3. Winnipeg Aqueduct	Shoal Lake Lake of the Woods Basin 49°37'N, 97°12'W	City of Winnipeg Red River Basin 49°52'N, 97°20'W	3 m^3/s	Municipal Supply	1919	City of Winnipeg
4. Portage Diversion	Assiniboine River 49°57'N, 98°29'W	Lake Manitoba 50°11'N, 98°23'W	(710 m^3/s)	Flood Control	1970	Province of Manitoba
5. Red River Floodway	Red River 49°45'N, 97°08'W	Red River 50°06'N, 96°56'W	(1700 m^3/s)	Flood Control	1969	Province of Manitoba
6. Seine River Floodway	Seine River Red River Basin 49°40'N, 96°38'W	Red River 49°42'N, 97°07'W	(85 m^3/s)	Flood Control	1961	Province of Manitoba
7. 8-Mile Channel Cutoff, Lake Winnipeg Control	Playgreen Lake Nelson Basin 54° 01'N 98° 18'W	Kiskittogisu Lake Nelson Basin 54° 06'N 98° 25'W	(1300 m^3/s)	Hydropower	1975	Manitoba Hydro
8. Pasquia Land Resettlement & Helldiver Lake Projects	Pasquia River Saskatchewan Basin 53° 36'N 101° 43'W	Carrot River Saskatchewan Basin 53° 45'N 101° 44'W	4.88 m^3/s	Flood Control Drainage Wildlife	1960	Province of Manitoba Ducks Unlimited

2.2 Correspondence (personal communication)

Limiting the literature survey to computer files might have lead to ommissions. Therefore, as a supplementary course of action, agencies, institutions and individuals likely to have worked in the area of interest were contacted. (A listing of respondents will be found in Appendix 6.3.) Telephone directories were used to select candidates in universities, government and consultant companies. A mailing list was prepared and a general letter of inquiry, along with an acknowledgment card (Figures 3, 4, Appendix 6.2) was forwarded to each candidate. The postage-paid card gave the recipient an efficient means of acknowledging our request and indicating his or her level of response. Telephone contact was used as a follow-up technique in cases where respondents identified more appropriate sources or it became apparent that good sources had been overlooked.

2.3 Screening

The search techniques generated a relatively large volume of information, much of it outside the specific objective of the survey. Consequently, criteria were established for use as a guide in screening out inappropriate material. The following definitions were used:

a. environment - those factors which act on a biological community residing in stream or lake water, bank or shoreline habitats and contiguous wetland areas.

b. effects - those changes which are a direct result of the diversion of water.

c. water diversion - the transfer of water, by man-made means, from one water course to another.

d. intrabasin transfer - a water diversion between two rivers in the same watershed.

e. interbasin transfer - a water diversion between two rivers which would normally have no fresh water connection.

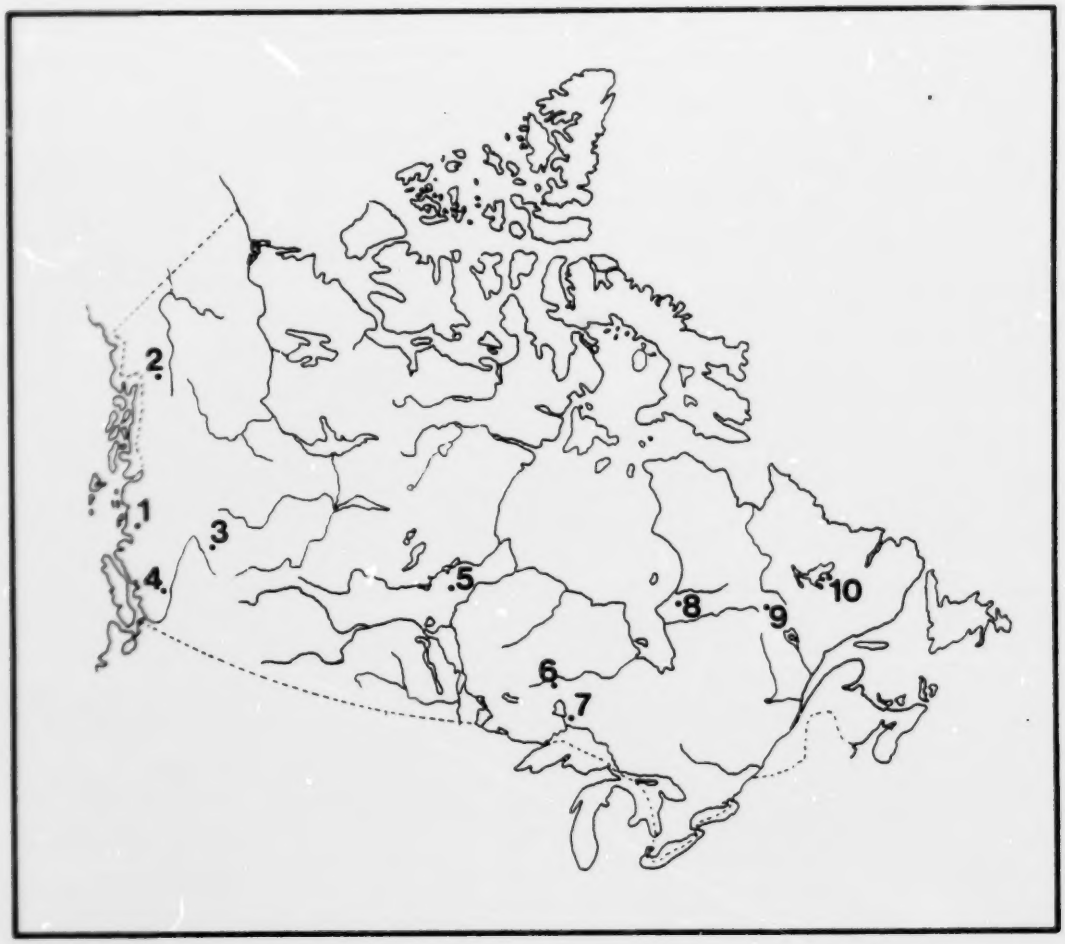
3.0 RESULTS

Sixty-one documents were selected by means of the procedure outlined in section 2.0. Most described events associated with eleven proposed or completed water diversion schemes. This section provides a location map followed by diagramatic plans, reference citations, design details and major environmental effects or concerns for each scheme. These project summaries are intentionally brief and interested parties should secure a hard copy of the respective reference material. The following sections encompass, respectively, bibliographic listing and reference annotations.

The ecological implications of reservoir development have been well reviewed in the Canadian (31, 16) and American (57) literature. For this reason, the environmental portion of the project summaries highlight effects caused by the diversion channel per se, altered downstream flows (donor and recipient basins) and, where applicable, lake storage.

The Directorate plans to revise this 1985 survey as new information comes to light. In this regard readers are asked to forward new (or overlooked) reports on the environmental effects of existing Canadian water diversions to:

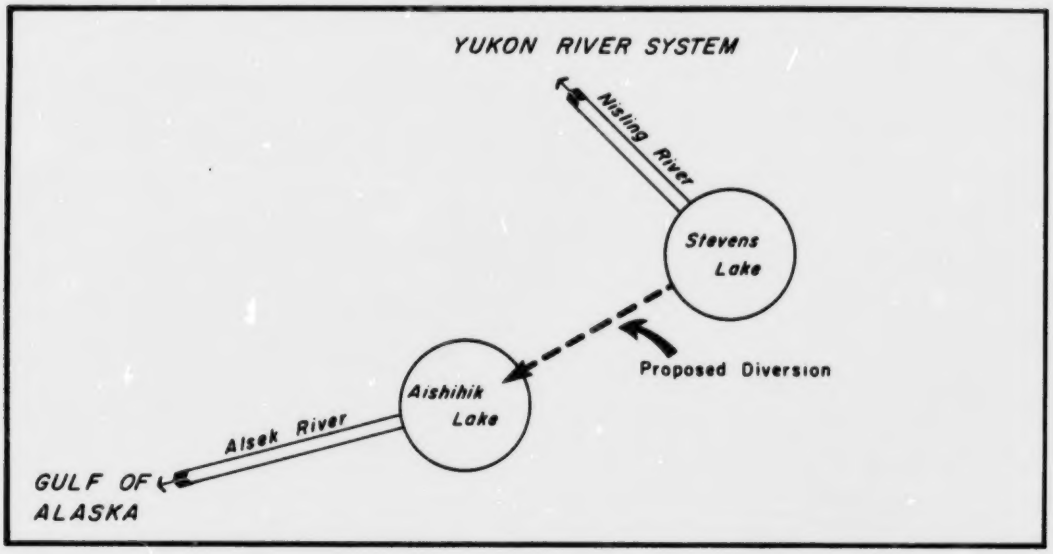
Environmental Assessment Biologist
Conservation and Protection
Inland Waters Directorate
Western and Northern Region
Environment Canada
1st Floor, Motherwell Building
1901 Victoria Avenue
Regina, Saskatchewan
S4P 3R4



1. Kemano I and II
2. Aishihik (proposed)
3. Bridge River
4. Mc Gregor (proposed)
5. Churchill River
6. Ogoki
7. Long Lake
8. Eastmain - Opinica (James Bay)
9. Caniapiscau (James Bay)
10. Churchill Falls

Figure 2: Location Map

3.1 Aishihik Diversion (Yukon - proposed)



references 15

type . . . . . interbasin

purpose . . . . . hydropower

major details . . . . . diversion of Stevens Lake (Yukon River) into Aishihik Lake (Alsek River - Pacific drainage)

status . . . . . on hold

environmental concerns

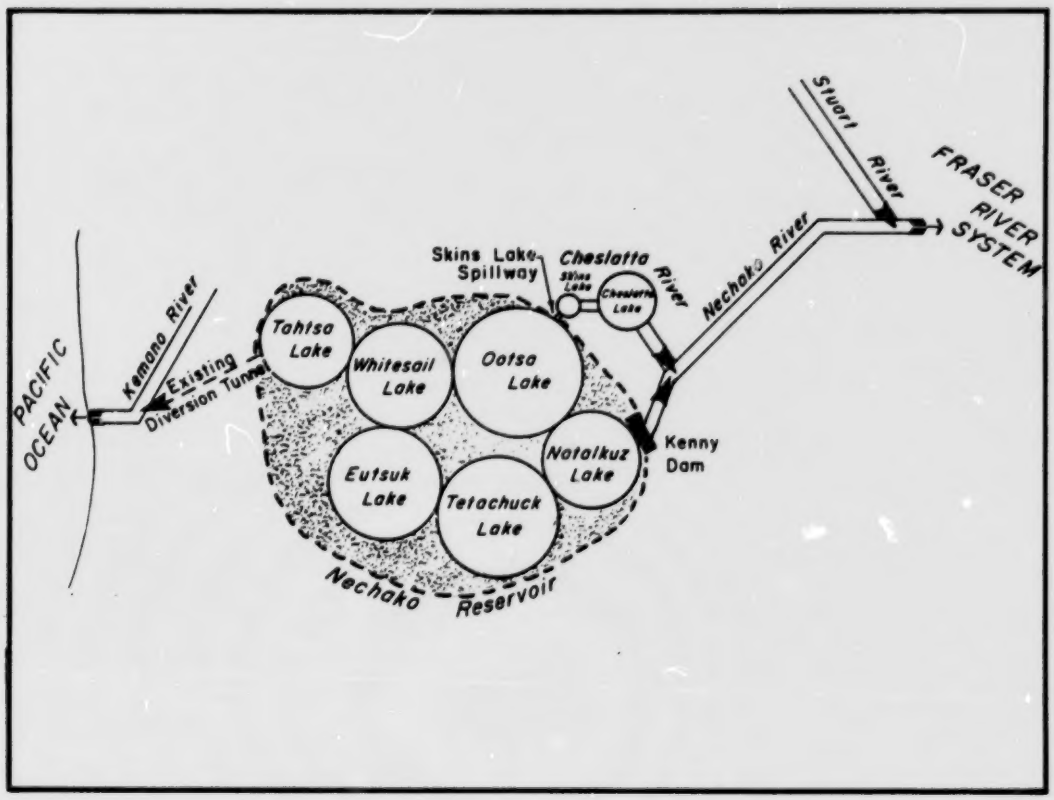
. donor system . . . . . Nisling River (Yukon River System)

- not reported

. receiving system . . . . .

- parasite transfer impacting Alsek River drainage salmon population.

3.2 Kemano I (British Columbia - existing)



references 7, 8, 13

type . . . . . .intrabasin

purpose . . . . . hydropower (flood control)

major details . . . . . Kenny Dam and Skins Lake spillway structures on the Nechako and Cheslatta rivers, created the 890 km^2 Nechako Reservoir by flooding a series of headwater lakes; a 10 km tunnel conveys water from the Nechako Reservoir to the powerhouse on the Kemano River.

status . . . . . completed 1959

environmental concerns

. donor system . . . . . Nechako watershed upstream of the Cheslatta River (Fraser River System)

- during reservoir filling (1952-55) no water was released to the Nechako, chinook salmon spawning ground was dewatered; initial releases from Skins Lake spillway caused massive erosion of stream channels draining Skins and Cheslatta lakes with resultant deposition of debris and silt on chinook spawning grounds; these factors combined contributed to a 60% decline in Nechako River chinook stock since 1952 (limited recovery has occurred in recent years).
- elevated Nechako water temperatures (reduced flows) and restrictive transportation flows continue to be a problem for salmonid stocks in Nechako system.

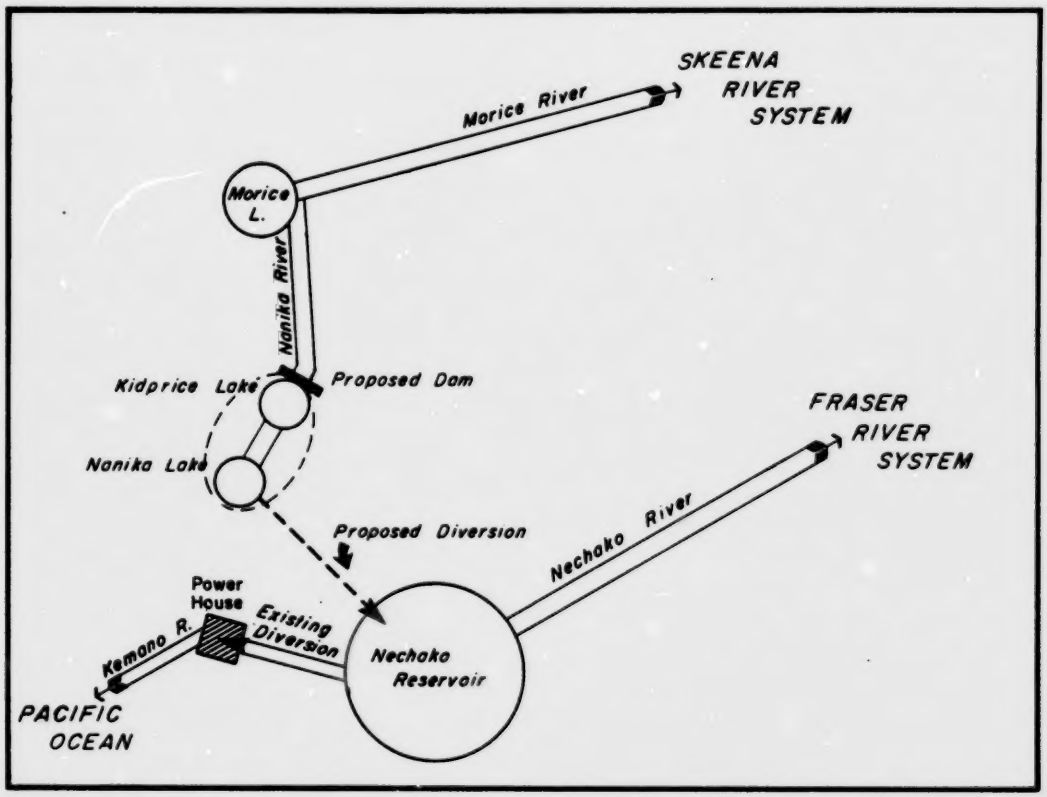
. receiving system . . . . . Kemano River

- flow increases during the two high runoff months (June/July) has resulted in some straightening of the main channel, an increase in main channel width of about 60% and an increase in total side channel length of about 250%. The river has not yet (1984) stabilized.
- increased flows may have improved the spawning and incubation environment for pink and chum salmon (average pink salmon escapement has increased significantly over the period of record, especially 1960 onward).
- coho escapements have declined since 1960.
- chinook salmon trend is not clear.

. general comments . . . . . .

- the references are the product of Department of Fisheries and Oceans and hence concentrate on anadromous salmonid stocks, no doubt the greatly altered hydrology and channel hydraulics has had some impact on resident fish species, but information on this was not located.

3.3 Kemano II (British Columbia - proposed)



references 7, 8, (13a), (44b)

type . . . . . interbasin

purpose . . . . . hydropower (aluminum production)

major details . . . . . 8 km long diversion tunnel connecting Nanika Lake to the Nechako Reservoir; 62% of mean annual flow in the Nanika River will be diverted.

status . . . . . on hold

environmental concerns

. donor system . . . . . Nanika and Morice Rivers (Skeena River system)

- reduced and altered flows would cause major channel changes and losses of side channel habitat, also changes in river temperature regime would occur (Nanika River)- expected result is a major loss of coho and chinook rearing habitat; increased winter flows may improve egg to fry and overwintering survival.
- reduced nutrient input to Morice Lake, plus earlier fry emergence in spring (higher temperatures) may lead to a net loss of sockeye production.

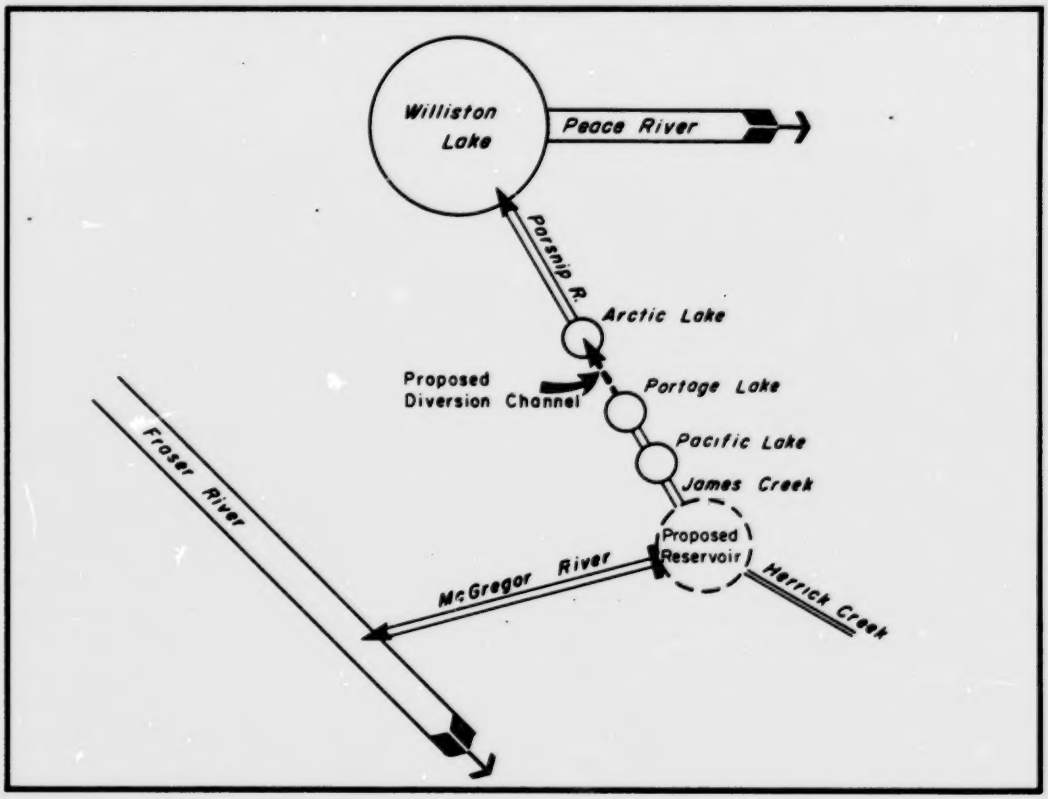
. receiving system . . . . . Kemano River

- mean annual flows in the Kemano River should increase by a factor of two. The Kemano River implications cannot be predicted with any certainty. However, should the river become single channelled, salmon production would be seriously threatened.

. general comments . . . . . .

- disease and parasite transfer is not a major concern (no important disease agent was found in donor waters).
- operation of the Nechako Reservoir will further reduce Nechako River flows. The system is presently a diminished river and further flow reductions will severely limit potential for chinook habitat improvement.

3.4 McGregor Diversion (British Columbia - proposed)



references	3, 6, 14, 40, 42, 53, 56
type	interbasin
purpose	hydropower (flood control)
major details	23,500 hectare reservoir, diversion channel at Artic/Portage lakes divide capable of passing a probable maximum flood flow of 4 400 m^3/s
status	on hold

environmental concerns

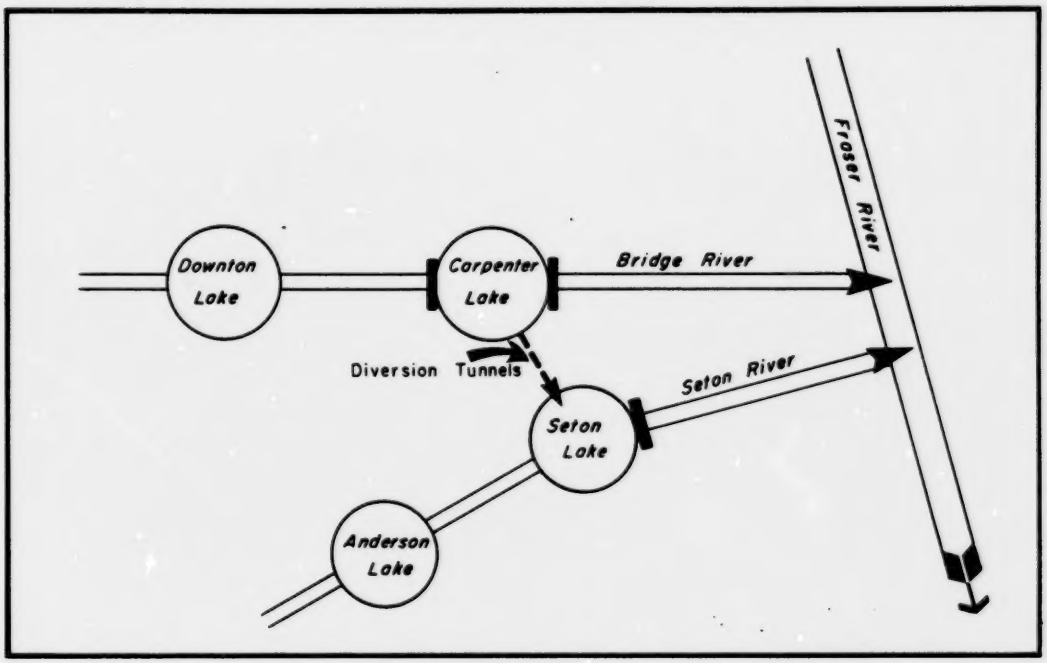
. donor system . . . . . McGregor River (Fraser River)

- water temperature increases, flow reduction, reduced water levels and degraded water quality causing negative impact on salmon fishery in Fraser basin.

. receiving system . . . . . Parsnip River (Peace River)

- channel degradation (3-5m) and flooding leading to loss of riverine wildlife habitat causing negative impact on wide range of wildlife species; sharply reduced or eliminated fish populations in divide lake(s) (Pacific, Portage and Arctic) and mainstem Parsnip River
- potential transfer of three exotic species of fish parasite into Peace Rver system resulting in economic impact on associated resource fishery.

3.5 Bridge River Diversion (British Columbia - existing)



references 31

type . . . . . intrabasin

purpose . . . . . hydropower

major details . . . . . diversion of Bridge River and Cayoosh Creek into Seton Lake through two tunnels, with a combined maximum discharge of 73 m^3/s (1955 to 1968)

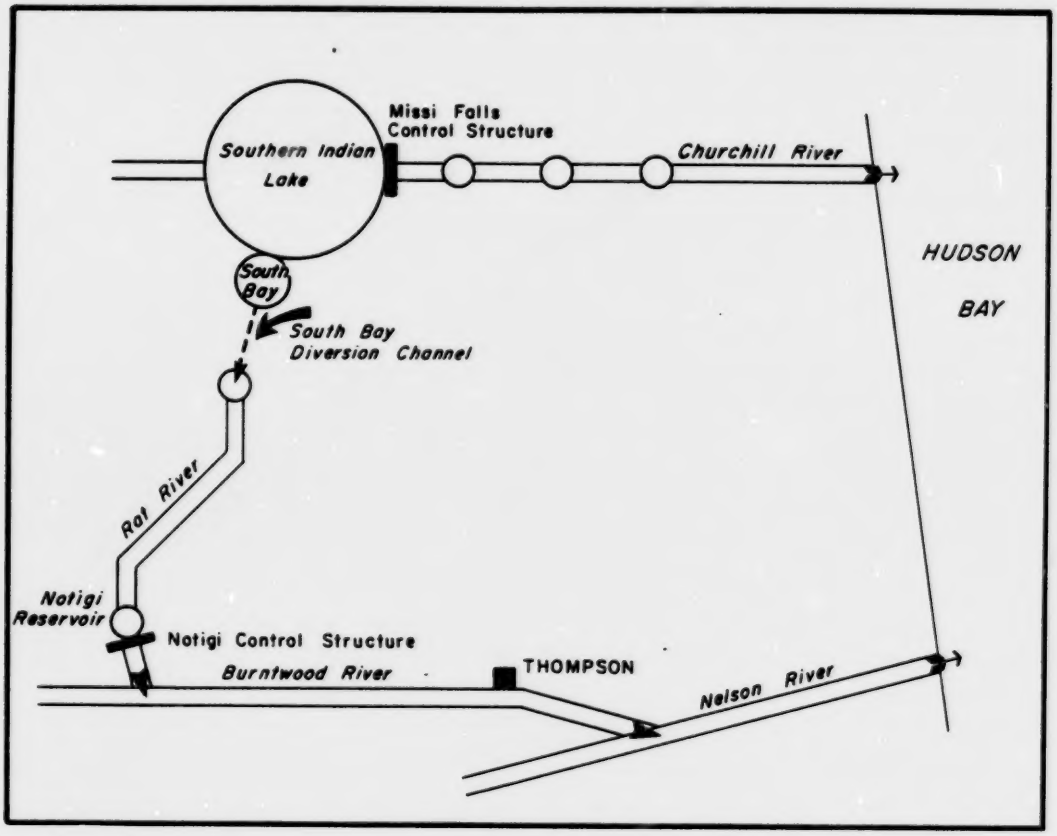
status . . . . . completed 1960

environmental concerns

. donor system . . . . . Bridge River/Cayoosh Creek
  - not reported

. receiving system . . . . . Seton Lake and River (Fraser River)
  - sockeye rearing capacity of Seton Lake reduced due to introduction of cold, turbid water; reduced temperatures in Seton Creek has probably had a beneficial effect on pink salmon production

3.6 Churchill Diversion (Manitoba - existing)



references 18, 19, 20, 21, 22, 29, 35, 36, 37, 41, 45, 46, 47, 49, 51, 58

type . . . . . interbasin

purpose . . . . . hydropower

major details . . . . . diversion of approximately 760 m^3/s (75% long term mean flow) from lower Churchill River through Rat-Burntwood River system into the lower Nelson River.

status . . . . . completed: 1976, full capacity 1977

environmental concerns

. **donor system** . . . . . **Churchill River**

- although presently unquantifiable, water quality has apparently changed in the lower Churchill river, for example, mean total phosphorus and aluminum, and turbidity have exhibited higher post-diversion levels.
- Southern Indian Lake (SIL) is experiencing severe shoreline erosion, a minimum 40 year stabilization period is projected; marginal alterations in profundal macroinvertebrate productivity, apparent increases in abundance and distribution of large zooplankton species (preferred food items for white fish and cisco); primary productivity has shown no significant change. Five years after impoundment classification of the white fish fishery was lowered to B grade (Continental) from A (Export) and the catch per unit effort (CPE) is 1/3 of the pre-impoundment mean, age distribution has not changed.

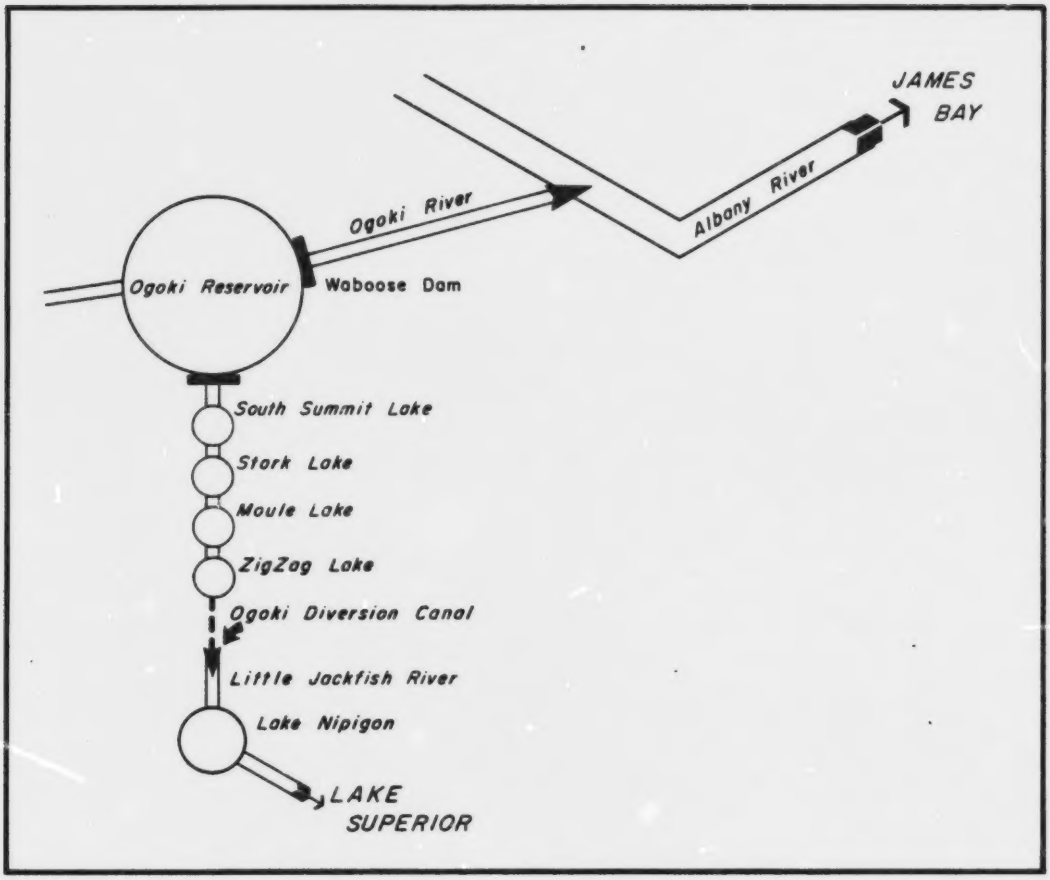
. **receiving system** . . . . . **Nelson River**

- winter run-off to the Nelson River estuary has increased by almost 50%, unfortunately the biological implications have not been reported.
- the Notigi Reservoir has united five headwater lakes in the Rat-Burntwood system and sever erosion is occurring in the river channel below the outlet due to dramatic flow increases (nine times increase in natural average flow at Thompson); again biological repercussions are not yet reported.

. **general comments** . . . . .

- increased fish mercury levels coincident with impoundment have lead to marketing restrictions; in general peak levels in predatory fish occurred in the Notigi Reservoir, moderate levels in lakes below the reservoir outlet, lowest levels in South Indian Lake; bioaccumulation of naturally occurring mercury due to mobilization from flooded soils is a suspected cause.

3.7 Ogoki Diversion (Ontario - existing)



references . . . . . 24, 28 (a & b)

type . . . . . interbasin (small scale)

purpose . . . . . hydropower

major details . . . . . headwater reservoir created in Ogoki River (Waboose Dam), water is redirected through the short Ogoki Canal to the Little Jackfish River (L.J.R.) in which flows increased from 4 m^3/s to 118 m^3/s (maximum 311 m^3/s)

status . . . . . completed 1943

environmental concerns

. donor system . . . . . Ogoki River (Albany River - James Bay)

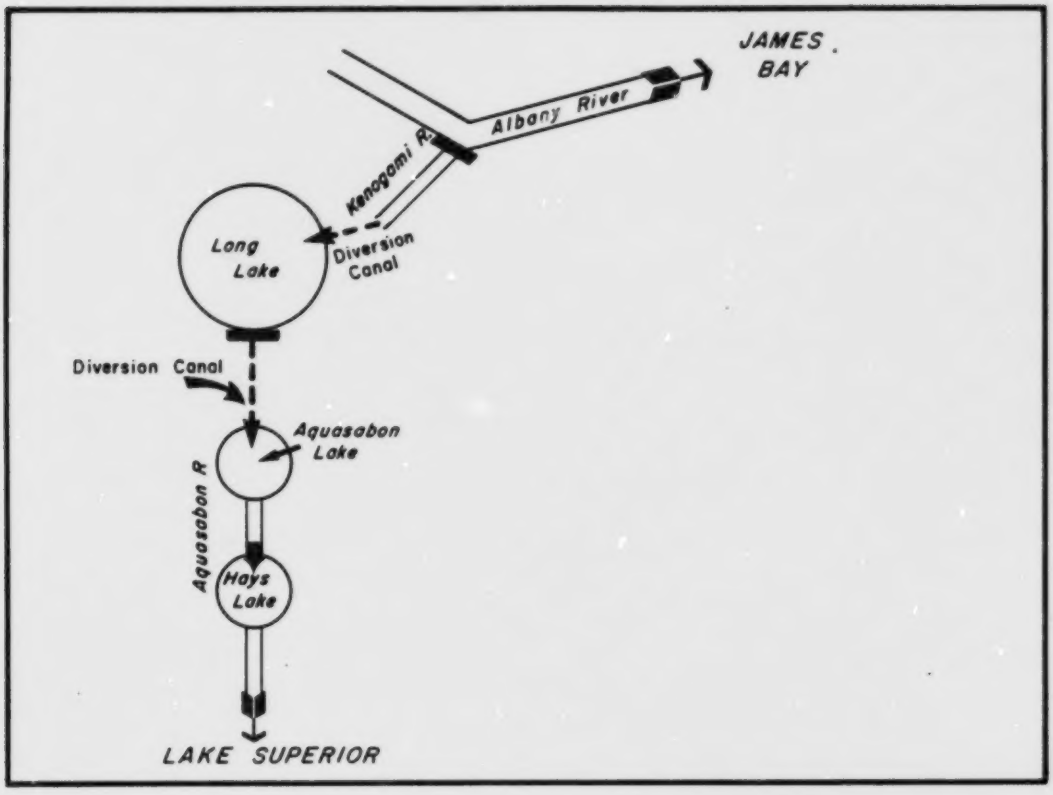
- severe flow reductions exposed fish habitat reducing productivity and preventing migrations, long stagnant reaches now exist, species diversity has declined; some recovery occurs downstream of tributary inputs; sporadic water releases perpetuate instability, maintaining streamside vegetation in early successional stages (good wildlife and waterfowl habitat)

. receiving system . . . . . Little Jackfish River (Lake Nipigon - Lake Superior)

- lower reaches of L.J.R. lost approximately 23 million cubic meters of sediment between 1943 and 1972, pre-diversion biological communities have been eliminated
- north end of Lake Nipigon which receives L.J.R. inflow has experienced severe siltation and turbidity problems, local fish composition has been altered, profundal macroinvertebrate community changed to burrowing forms (less attractive fish food)

. general comments . . . . . no major related socio-economic impacts were identified, turbity increases degrade predatory fish habitat

3.8 Long Lake (Ontario - existing)



references 28, 50

type . . . . . interbasin (small scale)

purpose . . . . . hydropower generation, pulpwood transportation

major details . . . . . interbasin canal to Long Lake from Kenogami River, 8.85 km canal from Long Lake to the Aquasabon Lake; average southward flow is 41.4 m^3/s

status . . . . . completed 1939

environmental concerns

. donor system . . . . . Kenogami River (Abany River - James Bay)

- flow prevention has created absolute habitat losses; decreased nutrient transfers and biological production, fish spawning disruptions; periodic flushing has uprooted some established riverside biological communities promoting temporal riverine ecological instability

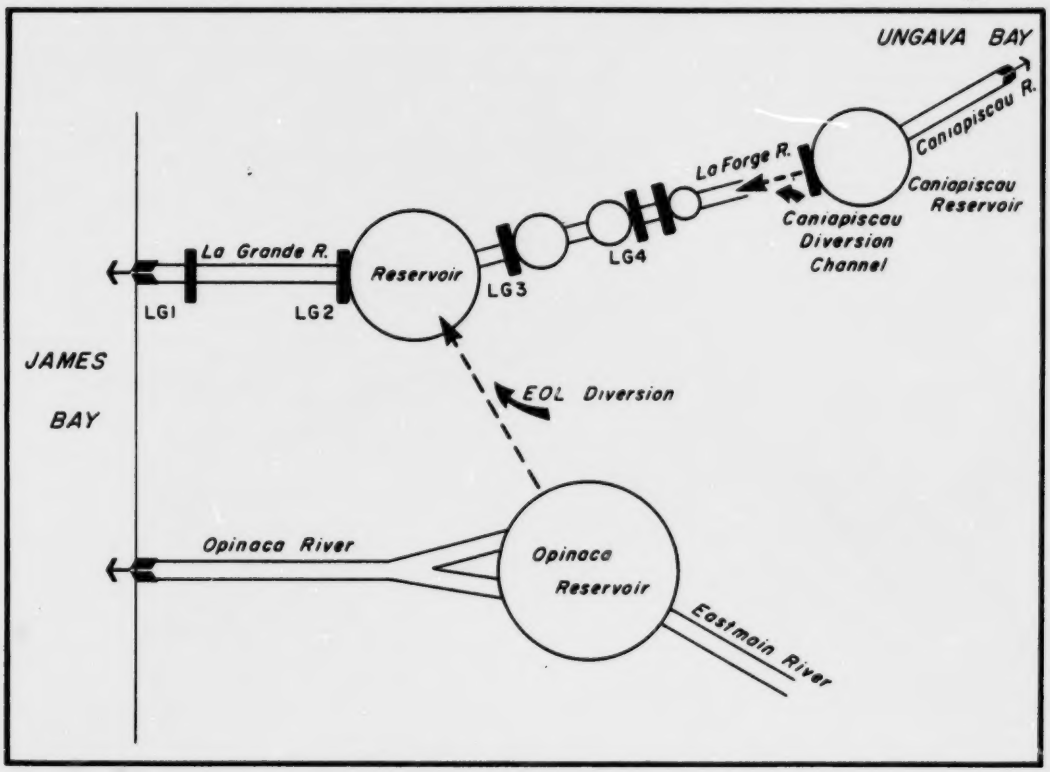
. receiving system . . . . . Aquasabon River (Lake Superior)

- ecological effect of diversion channel and inflow to Hays Lake (man-made reservoir) are not reported to be significant

. general comments . . . . .

- greatly enhanced log handling activities have created biological problems secondary to diversion effects per se,
- no major project related problems have been identified

3.9 Eastmain-Opinaca (EOL) Diversion (James Bay, Quebec - existing)



references 4, 12, 17, 23, 43, 51, 54

type . . . . . interbasin

purpose . . . . . hydropower

major details . . . . . Eastmain and Opinaca rivers diverted upstream of LG2 site through the Boyd-Sakami Lake system, annual mean flow increase will approximate 800 m^3/s.

status . . . . . completed

environmental concerns

. donor system . . . . . Eastmain-Opinaca Rivers
- severely reduced flows downstream from cut-off sites, remedial measures (weirs) have been constructed, limited anoxia during winter
- enrichment of zooplankton population in Eastmain River noted, especially below the weirs (lake like in composition); Opinaca River zooplankton remain riverine in character (low density)
- Opinaca benthos relatively unchanged since diversion
- based on catch results, Eastmain fish populations have declined, lake sturgeon and longnose sucker are becoming more dominant; although fines have been deposited on white fish spawning habitat, reproduction does not appear to be affected
- riparian vegetation has suffered, aquatic species are still largely absent from lower reaches of Eastmain
- wetland vertebrates are showing some recovery

. receiving system . . . . . La Grande River
- flow interruptions during filling (1978-79) caused greatly increased values for parameters associated with suspended matter along with upstream intrusion of cold saltwater below the LG1 site. Although these events may have created short term critical conditions for some aquatic organisms, there appears to have been little lasting impact on the fish stocks of the La Grande River. Recent evidence (82-83) suggests that these populations, especially Coregonids (favoured by natives), may be increasing.
- eventually a 5-fold increase in winter freshwater outflow will occur with a doubling of freshwater input to James Bay in the winter months; biological implications were not identified.

. general comments . . . . .
- fishery impacts predicted for the lower La Grande River appear to have little resemblance to what actually occurred.
- abnormally high mercury levels have been found in the system reservoirs.

3.10 Caniapiscau Diversion (James Bay, Quebec - existing)

references 4, 17, 43, 54

type . . . . . interbasin

purpose . . . . . hydropower

major details . . . . . diversions of waters of the upper basin of the Caniapiscau River (at Lake Duplanter) to the La Grande River (Laforge River). The resulting Caniapiscau reservoir with a total area, at maximum level of 4 299 km^2, is the largest in the James Bay complex (severe flow reductions in 1981-82 during filling), mean annual flow 650 cm^3/s.

status . . . . . flow diverted in 1981, reservoir filled in 1982-83

environmental concerns

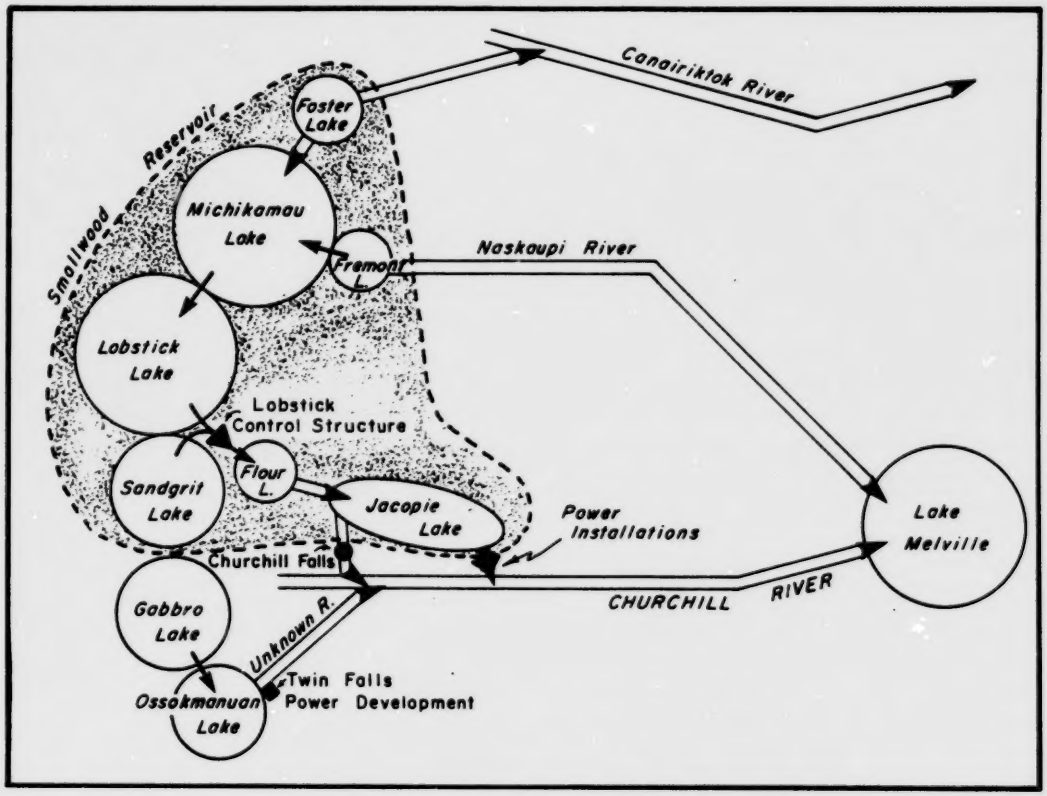
. **donor system** . . . . . Caniapiscau River (Koksoak River)

- substantial declines in flows have occurred since reservoir filling; biological implications were not specified.

. **receiving system** . . . . . La Forge River

- effects are not defined.

3.11 Churchill Falls (Labrador - existing)



references 25, 30

type . . . . . intrabasin/interbasin

purpose . . . . . hydropower

major details . . . . . the headwaters of the Naskaupi and Canairiktok Rivers are diverted into the Churchill River Basin, increasing its natural drainage area by approximately 23% (56,000 km^2 to 69,000 km^2).

status . . . . . complete

environmental concerns

. **donor system** . . . . . **Naskaupi and Canairiktok Rivers**

- As a result of the loss of some 7,000 km^2 of Naskaupi headwaters, the river channel is almost dry as far downstream as Wuchusk Lake (90 km below dykes). Alkalinity, calcium, nitrogen, sulfate and chloride values have risen. Although effect of flow reduction and water chemistry changes on fish populations are under investigation, results have not been reported.

. **receiving system** . . . . . **Churchill River**

- A survey of mercury levels in Labrador fish (1977-78) reported the highest values in fish from the Smallwood Reservoir and waters of the Churchill River downstream of the Lobstick Control Structure.

. **general comments** . . . . . .

- It appears flooding of the Smallwood Reservoir has accelerated the normal leaching rate of mercury into the aquatic environment.

4.0 BIBLOGRAPHY

Anon. 1971. "Ecological Effects of Diverting Water from the Mackenzie River Basin to the Saskatchewan-Nelson Basin". Canadian Wildlife Service, Edmonton, Alberta. (1)

------ 1972. "Effects of Diversion on Donor Basins; (A.) Mackenzie Basin, (B.) Churchill Basin". Appendix 8, Saskatchewan-Nelson Basin Board, Modern Press, Saskatoon. 414 pp. (2)

------ 1975. "A Preliminary Environmental Impact Assessment of the Effects of the McGregor River Diversion on the Parsnip River Valley, Vol. 1 - The Report". Environment Research Consultants, Vancouver, B.C. 75 pp. (3)

------ 1975. "James Bay Hydroelectric Project, a Statement of Environmental Concerns and Recommendations for Protection and Enhancement Measures." Lands Directorate, Environment Canada, Ottawa. 45 pp. (4)

------ 1978. "Hinds Lake Hydro-electric Project, Environmental Impact Statement". Newfoundland & Labrador Hydro. (5)

------ 1978. "The McGregor River Diversion Assessment on Its Impact on the Parsnip River Valley, Preliminary Report". Fish & Wildlife Branch, B.C. Department Recreation Conservation. 19 pp. (6)

------ 1979. "Salmon Studies Associated with the Potential Kemano II Hydroelectric Development" Vol 1 - Department of Fisheries and Oceans, Vancouver, British Columbia. 78 pp. (7)

------ 1979. "Chinook Salmon Studies on the Nechako River Relative to the Proposed Kemano II Power Development". Department of Fisheries and Oceans, Vancouver, British Columbia. 37 pp. (8)

------ 1981. "Bloody Creek Diversion Project, Environmental Overview". Montreal Eng. Company Ltd., Halifax. 73 pp. (9)

------ 1981. "Great Lakes Diversions and Consumptive Uses". Report to the International Joint Commission by the Int. Great Lakes Diversions and Consumptive Uses Study Board, Ottawa. (10)

------ 1983. "Environmental Impact Assessment: Lake Michel Hydro-electric Development". ShawMont Newfoundland Limited, Newfoundland & Labrador Hydro. (11)

------ 1984. "The Eastmain-Opinaca Diversion: Study of the Effects of Downstream Diversion Structures", Interim Report. Société d'Energie de la Baie James and the James Bay Remedial Works Corp. 50 pp. (12)

------ 1984. "Toward a Fish Habitat Decision on the Kemano Completion Project; A Discussion Paper". Fisheries & Oceans Canada. (13a)

------ 1986. "Water Transfers in the Prairie Provinces; A 1985 Inventory". Water Planning & Management Branch, Environment Canada, Regina. 69 pp. (13b)

Arai, H.P. and Mudry, D.R., 1983. "Protozoan and Metazoan Parasites of Fishes From the Headwaters of the Parsnip and McGregor Rivers, British Columbia: A Study of Possible Parasite Transfaunations". Can. J. Fish. Aquat. Sci. 40(10): 1676-1684. (14)

Arthur, J.R., Margolis, L. and Arai, H.P., 1976. "Parasites of Fishes of Aishihik and Stevens Lakes Yukon Territory Canada and Potential Consequences of Their Interlake Transfer Through a Proposed Water Diversion for Hydro Electrical Purposes". J. Fish. Res. Bd. Can. 33 (11): 2489-2499. (15)

Baxter, R.M. and Glaude, P., 1980. "Environmental Effects of Dams and Impoundments in Canada: Experience and Prospects." Can. Bull. Fish. Aquat. Sci. 205, 34 pp. (16)

Berkes, F., 1982. "Preliminary Impacts of the James Bay Hydroelectric Project, Quebec on Estuarine Fish and Fisheries." Artic 35(4):524-530. (17)

Bodaly, R.A., Erickson, R.N. and Fudge, R.J.P., 1980. "Pre- and Post-Impoundment Experimental Fish Catches, Southern Indian Lake, Manitoba 1972 - 1979". Can. Data Rep. Fish. Aquat. Sci. No 201, 78 pp. (18)

Bodaly, R.A., Hecky, R.E. and Fudge, R.J.P., 1984. "Increases in Fish Mercury Levels in Lakes Flooded by the Churchill River Diversion, Northern Manitoba." Can. J. Fish. Aquat. Sci. 41:682-691. (19)

Bodaly, R.A. Johnson, T.W.D., Fudge R.J.P. and Clayton, J.W., 1984. Collapse of the Lake Whitefish (Coregonus clupeaformis) Fishery in Southern Indian Lake, Manitoba, following Lake Impoundment and River Diversion." Can. J. Fish. Aquat. Sci. 41:692-700 (20)

Bodaly, R.A., Rosenberg, D.M., Gaboury, M.N., Hecky, R.E., Newbury, R.W. and Patalas, K., 1984. "Ecological Effects of Hydroelectric Development in Northern Manitoba: The Churchill-Nelson River Diversion", in "Effects of Pollutants at the Ecosystem Level", SCOPE, John Wiley and Sons Ltd. p. 273-309 (21)

Boothroyd, P.N., 1983. "Effect of the Churchill River Diversion on Waterfowl Use of the Lower Churchill River, Manitoba" in "Resources and Dynamics of the Boreal Zone". Assoc. Can. Univ. for Northern Studies. p. 443-457 (22)

Boucher, R., Wickham, P. and Roy, D., 1984. "Modifications Observées sur La Grande Rivière en aval du Réservoir de LG 2". Société d'Energie de la Baie James, Direction Ingeniere et Environment, Quebec. 109 pp. (23)

Bridger, K.C., 1978. "The Ogoki Diversion: Reservoir, Downstream, Diversion Channel and Receiving Water Body Effects." unpub. M.A. thesis, University of Waterloo, Ontario. (24)

Bruce, W.J., and K.D. Spencer. 1979. "Mercury levels in Labrador fish, 1977-78". Can. Ind. Rep. Fish. Aquat. Sci. 111: 12 pp. (25)

Davies, L.B. and Shumuk, Y., 1979. "Prediction of Some Effects of a Major Interbasin Diversion by use of a Flow-Sediment Model" in "River Basin Management," Vol. 1. Canadian Society for Civil Engineering. pp. 211-232. (26)

Day, J.C., 1985 "Canadian Interbasin Diversions". Inquiry on Federal Water Policy, Research Paper #6, Environment Canada, Ottawa, K1A OH3. 110 pp. (27)

Day, J.C., Bridger, K.C., Peet, S.E. and Friesen, B.F., 1983. "Experience with Diversions into the Great Lakes: The Ogoki and Long Lake Projects." presented at the March 1983 "Symposium on Diversion of Great Lakes Water: Critical Resources - Critical Issues", West Michigan, Kalamazoo 49008. (28)

Dickson, I.W., 1975. "Hydroelectric Development of the Nelson Rivers System in Northern Manitoba" J. Fish. Res. Bd. Can. 32(1): 106-116 (29)

Duthie, H.C. and Ostrofsky, M.L., 1975. "Environmental Impact of the Churchill Falls (Labrador) Hydroelectric Project: A Preliminary Assessment". J. Fish. Res. Bd. Can, 32: 117-125. (30)

Geen, G.H. and Andrew, F.J., 1961. "Limnological Changes in Seton Lake Resulting from Hydroelectric Diversions". Int. Pacific Salmon Fish. Comm., Progress Rep. No. 8. 73 pp. (31)

Geen, G.H., 1974. "Effects of Hydroelectric Development in Western Canada on Aquatic Ecosystems." J. Fish. Res. Bd. Can. 31 (5): 913-927. (32)

Golubev, G. 1978. "Environmental Issues of Large Interregional Water Transfer Projects" in "Water Development, Supply and Management" Vol. 6 Pergamon Press, Oxford, New York. pp 177-186. (33)

Golubev, G., Grin G., Melnikova, G. and Whetstone, G. 1978. "Bibliography on Interregional Water Transfers" in "Water Development, Supply and Management" Vol. 6. Pergamon Press, Oxford, New York. pp. 187-210. (34)

Guilbault, R.A., Gummer, W.D. and Chacko, V.T., 1979. "The Churchill Diversion: Water Quality Changes in the Lower Churchill and Burntwood Rivers". Water Quality Interpretative Rep. No. 2, Inland Waters Directorate, Environment Canada. (35)

Hecky, R.E. and Guildford, S.J., 1984. "Primary Productivity of Southern Indian Lake before, during and after Impoundment and Churchill River Diversion." Can. J. Aquat. Sci. 41:591-604. (36)

Hecky, R.E. and McCullough, G.K., 1984. "The Landsat Imagery of Southern Indian Lake: a Remote Perspective on Impoundment and Diversion" Can. Tech. Rep. Fish. Aquatic Sci. 1266. 25 pp. (37)

Kellerhals, R., Church, M. and Davies, L.B., 1979. "Morphological Effects of Interbasin River Diversions". Can. J. Civ. Eng. (6): 18-31. (38)

Lau, Y.L., Krishnappan, B.G. and Engel, P., 1984. "Effects of Diversions on River Regime". National Water Research Institute, Burlington, Ontario. 19 pp. (39)

Lindsey, C.C., 1957. "Possible Effects of Water Diversions on Fish Distribution in British Columbia". J. Fish. Res. Board Can. 14: 651-668. (40)

McCullough, G., 1981. "Water Budgets for Southern Indian Lake, Before and After Impoundment and Churchill River Diversion, 1972-1979". Can. Manuscr. Rep. Fish. Aquat. Sci. No. 1620. 26 pp. (41)

McLeod, G.D., 1979. "McGregor River Diversion, Fraser River Water Temperature Study" in "River Basin Management", Vol. I, Canadian Society of Civil Engineering. pp 180-195. (42)

Marier, V., 1984. "Environmental Monitoring of the La Grande Hydro-electric Complex". Environment Canda, James Bay and Northern Quebec Office. 141 pp. (43)

Micklin, P.P., 1985. "The Vast Diversion of Soviet Rivers". Environment 27(2): 12-25. (44a)

Mundie, J. H. and Bell-Irving, R., 1986. "Predictability of the Consequences of the Kemano Hydroelectric Power Proposal for Natural Salmon Populations." Can. Wat. Res. J. 11 (1): 14-25. (44b)

Newbury, R.W. and McCullough, G.K., 1983. "Shoreline Erosion and Re-establishment in a Permafrost-Affected Impoundment" in Permafrost Fourth International Conf., Proceedings. Nat. Academy Press, Wash. D.C. ISBN 0-309-03435-3. (45)

Newbury, R.W., McCullough, G.K. and Hecky, R.E., 1984. "The Southern Indian Lake Impoundment and Churchill River Diversion." Can. J. Fish. Aquat. Sci. 41:548-557. (46)

Newbury, R.W. and McLeod, S.L., 1973. "Environmental Impact Assessment Methodology and Techniques for Assessing the Impact of the Churchill River Diversions" in "Proc. Nat. Conf. E.I.A.: Philosophy-Methodology". Aqassiz Center for Water Studies, Winnipeg, Man. (11) 188-207. (47)

Noton, L.R. and Chymko, N.R., 1977. "Water Quality and Aquatic Resources of the Beaver Creek Diversion System". Syncrude Env. Res. Mono. 1978-3. (48)

Patalas, K. and Salki, A., 1984. "Effects of Impoundment and Diversion on the Crustacean Plankton of South Indian Lake." Can. J. Fish. Aquat. Sci. 41:613-627. (49)

Peet, S.E. and Day J.C., 1980. "The Long Lake Diversion: An Environmental Evaluation." Can. Wat. Res. J. 5(3): 34-48. (50)

Prinsenberg, S.J., 1980. "Man-Made Changes in Freshwater Input Rates of Hudson and James Bays." Can. J. Fish. Aquat. Sci. 37:1101-1110. (51)

Quinn, F., 1981. "Water Transfers - Canadian Style". Can. Wat. Res. J. 6(1): 64-75. (52)

Seagal, G.C. and Pugh, M.F., 1980. "A Perspective on Water Transfer: McGregor Diversion Project". Reid Crowther & Partners Limited, (Presented at Canadian Water Resources Association Conference, 1980). (53)

Soucy, A., 1978. "James Bay Hydroelectric Development: Evolution of Environmental Considerations." Can. Wat. Res. J. 3(4): 54-88. (54)

Stewart, K.W., Suthers, I.M. and Leavesley, K. 1984. "New Fish Distribution Records in Manitoba and the Role of a Man-made Interconnection Between Two Drainages as an Avenue of Dispersal." Canadian Field Naturalist (to be published). (55)

Tutty, B.D., 1979. "1977 Chinook Salmon Investigations Associated with the McGregor River Diversion". Fisheries and Marine Service, Dept. of Fisheries & Oceans. (56)

Walburg, C.H., Novotny, J.F., Jacobs, K.E., Swink, W.D., Campbell, T.M., Nestler, J. and Saul, G.E., 1981. "Effects of Reservoir Releases on Tailwater Ecology: A Literature Review". Technical Report E-81-12, U.S. Dept. of the Interior, FWS. 188 pp. (57)

Wiens, A.P. and Rosenberg, D.M., 1984. "Effect of Impoundment and River Diversion on Profundal Macrobenthos of Southern Indian Lake, Manitoba." Can. J. Aquat. Sci. 41:638-648. (58)

5.0 ANNOTATIONS

Anon. 1971. "Ecological Effects of Diverting Water from the Mackenzie River Basin to the Saskatchewan-Nelson Basin". Canadian Wildlife Service, Edmonton, Alberta. (1)

This report discusses the potential ecological implications of diverting water from the Mackenzie River system into the Saskatchewan-Nelson Basin. The muskrat, beaver, waterfowl and other biological resources of the Slave, and Peace-Athabasca river deltas are reviewed in the context of water withdrawals. A summary of basic conclusions and bibliography are provided.

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Anon. 1972. "Effects of Diversion on Donor Basins; (A.) Mackenzie Basin, (B.) Churchill Basin". Appendix 8, Saskatchewan-Nelson Basin Board, Modern Press, Saskatoon. 414 pp. (2)

Early in the course of this study, the Saskatchewan-Nelson Basin Board decided that some consideration should be given to subjects other than water supply even though no such provision had been made in its terms of reference. Arrangements were made for knowledgeable persons to report on each of eight topics; fish and the biological system, recreation, wildlife, river regime, water quality, groundwater, the effects of diversion on the Churchill River System, and the effects of diversion on the Mackenzie River System. A complete study of each topic was not possible within the framework of the SNBB Study, so a general appraisal was made under three headings. The report on each topic is reproduced in full in Appendices 7 and 8. This appendix (8) contains the two reports on the possible effects of diversion on donor basins, one for the Mackenzie River System and one for the Churchill. Effects considered are: 1. morphology, 2. water quality, 3. navigation, 4. wildlife and ecology, 5. fisheries, and 6. hydro-electric power, 35 Fig., 27 tab.

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------- 1975. "A Preliminary Environmental Impact Assessment of the Effects of the McGregor River Diversion on the Parsnip River Valley, Vol. 1 - The Report". Environment Research Consultants, Vancouver, B.C. 75 pp. (3)

The unregulated diversion of the McGregor River into the Parsnip River Valley will cause major physical change to the river channel and damage to the valley lowlands. The river will widen, deepen and flatten its gradient and change its meander pattern. Preliminary engineering and environmental studies indicate that the river flows will flood valley bottom land, causing the removal of mineral and organic soils and extensive areas of vegetation. During the stabilization period, the vegetation and aquatic habitats will be removed and destroyed in a portion of the valley lowland. Adjacent habitats will be altered because of prolonged periods of inundation by moving and still water. The damage to the terrestrial and aquatic habitats will cause the removal of wildlife populations from a majority of the lowland area. Fisheries populations in the divide lakes (Pacific, Portage and Arctic) and in the mainstem Parsnip River will be sharply reduced in numbers and possibly eliminated. There will be several negative impacts to the valley environment associated with the construction of access roads and facilities at the divide. However, certain impacts will have a positive effect on the environment while others will require caution in the construction and operation of the diversion. Mitigation measures have been suggested, which, if feasible, could reduce the severity of impacts.

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------ 1975. "James Bay Hydroelectric Project, a Statement of Environmental Concerns and Recommendations for Protection and Enhancement Measures." Lands Directorate, Environment Canada, Ottawa. 45 pp. (4)

In 1971 Environment Canada began conducting a series of studies pertaining to matters of national interest in the James Bay area. In the process the expertise that developed identified a number of specific environmental concerns related to the James Bay hydro development. This document presents these concerns and discusses remedial measures.

A number of broad conclusions were arrived at. Among others it was concluded that the impact on waterfowl nesting habitat as a result of flooding would be extensive, but not serious in view of the size of the area. Cumulative effects were of concern. However, compensation through environmental enhancement was felt possible.

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A major concern was the Caniapiscau diversion, resulting in downstream impacts to Atlantic salmon resources. Also a high concern was the effects of the flow modifications downstream from LG-1. In the lower La Grande, the mean annual flow will be practically doubled although it will still be less than the natural peak flows. Concern stemmed from the consequent new patterns of erosion and siltation, saline and freshwater changes and changes in water temperature, all of which would most likely adversely affect freshwater and anadromous fish reproduction. It was felt that these problems could be minimized by carefully planning and environmental design involving protective and enhancement measures.

Since the possibility of a complete and permanent flow interruption of the Eastmain and Opinaca rivers could not be ruled out, this diversion was a matter of prime concern. A full and permanent flow interruption would result in a large-scale destruction of the existing downstream biota. Further, it would result in the loss of the estuary and possibly much hardship to the anadromous whitefish. This problem can only be properly mitigated by ensuring that the flow never drops below the level of the lowest natural winter flow (estimated at 122 m^3/s) and by developing a comprehensive and carefully researched environmental design which would derive maximum benefit from this flow.

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------ 1978. "Hinds Lake Hydro-electric Project, Environmental Impact Statement". Newfoundland & Labrador Hydro. (5)

The Hinds Lake Project is a hydroelectric power development in western Newfoundland, which entails raising the water level of the lake approximately 5 meters. The water will be contained by two dams, the Hinds Lake Dam and the Eclipse Dam. A 6.1 km long power canal will carry the water to Grand Lake. The report gives a detailed description of the project. In accessing the possible environmental impact of this project, the report presents information on the fisheries in the area, caribou migration, moose population and fur-bearing animals. Construction of temporary access roads may lead to increased hunting and may influence caribou migratory behaviour. The construction of a permanent access road from Howley should have a positive effect on recreational use of land bordering Grand Lake. Seasonal flooding will cause loss of spawning and rearing habitats and changes in food supply for brook trout, land locked salmon and stikleback. Initiation of construction activities will result in significant short-term social impact on the closer communities of Howley and Deer Lake, however, the overall socio-economic impact appears limited.

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------ 1978. "The McGregor River Diversion Assessment on Its Impact on the Parsnip River Valley, Preliminary Report". Fish & Wildlife Branch, B.C. Department Recreation Conservation. 19 pp. (6)

This document was prepared under arrangement with the Canada-British Columbia Fraser River Joint Advisory Board's 'Fraser River Upstream Storage Review Report' dated December 1976. This document provides data from a study designed to assemble information regarding the Parsnip River Valley. The report describes the valley in its present form and predicts the environmental impact that would result from the diversion of a major portion of the McGregor flowage down the Parsnip Valley as proposed in the plans to build a dam at the lower canyon of the McGregor River. 3 Ref, 5 App, 4 Tab, 6 Plates.

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------ 1979. "Salmon Studies Associated with the Potential Kemano II Hydroelectric Development" Vol 1 - Department of Fisheries and Oceans, Vancouver, British Columbia. 78 pp. (7)

The Kemano II project is in effect the second stage of a hydro-electric development which was constructed in the mid-1950's. During the early 1950's when the development was licensed and constructed there was a lack of public and political awareness about multiple resource use concepts and environmental issues.

Early in 1974 discussions were initiated between representatives of B.C. Hydro and Power Authority, the federal Fisheries and Marine Service (Department of Fisheries and Oceans, Canada), the International Pacific Salmon Fisheries Commission and the provincial Fish and Wildlife Branch. It was agreed that the fish and wildlife agencies would submit an outline of their environmental concerns and a proposal for future studies which they considered necessary for a sufficient assessment of the environmental problems.

These were forwarded to B.C. Hydro on March 4, 1974. On April 26, 1974, B.C. Hydro indicated that it was prepared to fund the studies to the extent indicated in the cost estimates and the studies commenced immediately.

This report summarizes the results and conclusions of all biological, physical and socio-economic studies conducted on the Kemano II development by the Fisheries and Marine Service and the International Pacific Salmon Fisheries Commission.

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------ 1979. "Chinook Salmon Studies on the Nechako River Relative to the Proposed Kemano II Power Development". Department of Fisheries and Oceans, Vancouver, British Columbia. 37 pp. (8)

The Nechako River, which originates in the eastern slopes of the Coast Range, historically flowed in an easterly direction through Eutsuk, Tetachuk, Ootsa and Natalkus Lakes and then north-easterly to join the outflow of Fraser Lake. Construction of the Kenney Dam (Kemano I) at the head of Grand Canyon on the Nechako River created a reservoir which flooded this series of lakes to provide storage for the Kemano power plant.

Chinook salmon spawn throughout the Nechako River downstream of its confluence with the Cheslatta River. The combined effects of flow reduction and siltation of spawning grounds associated with this diversion development resulted in a reduction of these populations.

In August 1972, the British Columbia Energy Board released a report on power requirements and potential developments in the province. The report contained a proposal for expansion of the initial development (Kemano I), including diversion of water from Nanika, Morice and Dean Rivers and a further diversion from the Nechako River.

The federal Fisheries and Marine Service considered that the flow release recommended by the Energy Board would not be adequate to maintain chinook salmon stocks in the upper Nechako River. In addition, the proposed diversion would endanger sockeye salmon which migrate through the lower Nechako River into the Stuart and Fraser Lake systems. These concerns were subsequently expressed to British Columbia Hydro and Power Authority who agreed to finance further studies on the Nechako River as well as the Nanika and Morice Rivers. In the Nechako River, studies were undertaken by the Fisheries and Marine Service and the results are presented in this report.

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------ 1981. "Bloody Creek Diversion Project, Environmental Overview". Montreal Eng. Company Ltd., Halifax. 73 pp. (9)

This report describes the environmental implications of redevelopment of existing storage dams at Dalhousie and Corbett Lakes, and construction and operation of a pumphouse at the lower end of Dalhousie Lake to move flow over the height of land into the Paradise system. The objective of the study was to identify probable impacts associated with the redevelopment and identify any mitigating measures that could be incorporated into project construction or operation. Part II of the report describes the proposed diversion project and the relevant features of the biophysical environment within the study area. The

existing environment is described in relation to natural conditions and conditions imposed by the original hydro development. In Part III the environmental interactions associated with construction of the Bloody Creek diversion project are reviewed using an environmental matrix. The potential interactions, assuming no mitigating measures are applied, have been described in terms of minor, intermediate and major impacts. The matrix also shows where no interactions are expected. It is concluded that development of the diversion project will have a relatively small impact on the environment within the drainage area of the storage reservoirs. The previous storage dams will be increased in height by about 1 m and the surface area of the reservoirs will be increased by approximately one-third. At maximum water levels, the two storage reservoirs will be joined and a canal will be constructed to allow withdrawal of water from both reservoirs over a 1.5 m drawdown. The impact of the proposed project on the reservoir areas and along the diversion route is considered small. The increased size of the storage reservoirs and operation of the project are not expected to affect fish populations to a significant degree. In general, the areas affected by the storage reservoirs and the diversion flow are not productive woodland and do not appear to be important to wildlife. The major potential impact of the proposed project is associated with the reduction of stream flow in sections of Bloody Creek below the diversion. Only the lower 3.9 km of Bloody Creek is accessible to anadromous fish, but an additional 6.1 km supports populations of speckled trout. To maintain these fish populations at near current levels, maintenance flows from Dalhousie Lake of 0.06 cubic meter per second from June to October and 0.25 cubic meter per second from November to May have been requested by Fisheries and Oceans Canada.

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------ 1981. "Great Lakes Diversions and Consumptive Uses". Report to the International Joint Commission by the Int. Great Lakes Diversions and Consumptive Uses Study Board, Ottawa. (10)

This report was submitted to the International Joint Commission by the Great Lakes Diversion and Consumptive Uses Study Board in September 1981. The Board was established in May 1977 subsequent to a reference from the Governments of the United States and Canada to the IJC. The study had two distinct components: diversions and consumptive uses. In this study diversion is defined as a transfer of water either into the Great Lakes watershed from an adjacent watershed, (or vice versa) or from the watershed of one of the Great Lakes into that of another. The study findings, as well as Board conclusions and recommendations are included in the report.

The diversions component of the study primarily focused on four existing major diversions: the Ogoki, Long Lac, Michigan Lake at Chicago and the Welland Canal. A number of very small diversions which came to the Board's attention are briefly discussed. Hydrologic, economic and environmental effects of a change in the regime of Great Lakes levels and flows are addressed.

The environmental evaluation was limited by inadequate ecological and other relevant data. However, the Board did examine, in the report, the subjects of fisheries, wildlife/wetlands and water quality.

It was concluded that implementation of the maximum-effect diversion scenario (greatest reduction in mean lake levels) should not produce any significant social effects. Population growth trends would not be directly affected; however, adverse impacts on waterborne commerce and power production could induce population shifts. Hunting pressure could shift from wetland-dependent game to upland species. Non-consumptive wildlife-related recreation could experience a slight decline. Beach recreation would likely benefit by more exposed shoreline, but recreational boating could be negatively affected due to a reduction in water depth in shallow areas such as the connecting channels, harbours and bays. Adverse impacts to the sport fishery could also be incurred by lowered water levels. Water quality would not be significantly affected.

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------ 1983. "Environmental Impact Assessment: Lake Michel Hydro-electric Development". ShawMont Newfoundland Limited, Newfoundland & Labrador Hydro. (11)

This report discusses a study of the aquatic environmental impact of the proposed Lake Michel hydroelectric development. The project site is located about 50 kilometres southeast of Hawkes Bay in the Long Range Mountains of the Great Northern Peninsula of Newfoundland. The project involves the regulation of flow from one of the headwaters of the River of Ponds to a generating station below the escarpment. To provide uniform flow to the station, a headwater of the Portland Creek system will be diverted to supplement flow in the River of Ponds. A storage reservoir will also be created on Lake Michel, a large headwater lake of River of Ponds, about 10 kilometres from the head pond of the generating station.

Fish populations in streams and lakes to be affected directly by the project were sampled. Present fish populations were surveyed, fish spawning habitat was mapped and standing crops of lake benthic invertebrates and zooplankton, two important groups of fish food organisms which would be affected by water level regulation, were sampled.

Stream cross-section and flow data were collected and a 20-year flow record was estimated for various parts of the two systems. These were used to predict changes in flow and water level. Bathymetric charts were prepared for Lake Michel and for the lake that will become the headpond reservoir. Since the Lake Michel project could alter lake and stream water chemistry, water samples were collected and analyzed to provide background chemical data. Effects of the project on fish populations and invertebrates were predicted, recommendations for mitigation were made and a monitoring program was recommended.

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------ 1984. "The Eastmain-Opinaca Diversion: A Study of Effects of Diversion Structures." Interim Report, Scoiété d'energie de la Baie James, Montreal 49 pp. (12)

The Eastmain-Opinaca-La Grande (EOL) diversion involved rerouting towards the La Grande River basin, of a significant portion of the waters of the upper basin of the Eastmain and the Opinaca rivers, as well as those of the Petite Opinaca River.

Downstream from cutoff sites flows in the three rivers were greatly reduced as a result of the diversion. To offset the negative effects of the reduced flow, in 1981 and 1982 the Société d'énergie de la Baie James (SEBJ) and the James Bay Remedial Works Corporation (SOTRAC) undertook remedial measures: the measures included the construction of one weir along the Opinaca River and two weirs along the Eastmain River, as well as seeding and transplanting vegetation along exposed shoreline of the two rivers.

In addition, in 1980 SEBJ and SOTRAC, in collaboration with the Cree Regional Authority (CRA) and the Cree communities concerned set up a five-year monitoring program to keep track of the biophysical changes connected with the reduction in flow in the Eastmain, Opinaca and Petite Opinaca rivers and to assess the effectiveness of corrective measures.

This interim report outlines studies carried out in 1983. A comprehensive report dealing with the whole of the five-year program will be published at the beginning of 1985.

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------ 1984. "Toward a Fish Habitat Decision on the Kemano Completion Project; A Discussion Paper". Fisheries & Oceans Canada. (13a)

The Kemano Completion Project (Kamano II) is massive. The project entails the construction of two aluminum smelters. The power to operate the smelters would be generated by an additional powerhouse to be built at Kemano and transmitted via new transmission lines to the B.C. Grid System.

The Kemano Completion project directly threatens the salmon stocks in the Fraser River system. Several species would be impacted in the Nanika and Morice rivers as a result of the diversion of the Nanika River. All five species of Pacific Salmon and the eulachon populations of the Kemano River would be impacted. The potential exists for significant downstream effects in the Skeena and Fraser River.

The principal impacts stem from the major changes in the flow regimes of the rivers affected by the project. Sixty-two percent of the mean annual flow in the Nanika River will be diverted to the Nechako Reservoir and this will primarily occur in the months of June through August. The existing, partially regulated flow of the Nechako River will be reduced by a further 80%. The diverted water from the Nechako and Nanika rivers will be discharged into the Kemano River, where the mean annual flow will increase approximately by a factor of two. A 52 square kilometer (20 sq. mile) new reservoir will be created, flooding 14.6 sq. kilometers (5.6 sq. miles) of land between Nanika and Kidprice Lake. In its review the Department has attempted to identify likely impacts, possible solutions and areas of uncertainty and risk.

The principal impacts of the Nanika diversion relate to the survival of juvenile coho and chinook rearing in the Nanika River and juvenile sockeye rearing in Morice Lake. The reduced flows and altered flow regime would cause major channel changes and losses of side channel habitat. Likely significant changes in the river temperature regime would occur. Some opportunity exists for mitigation.

The Nechako River is already a diminished river. There is no certainty that the river currently has sufficient rearing capacity to meet its potential chinkook salmon production targets and there is no belief that Alcan's proposal will permit the maintenance of current production which is substantially less than the target.

The impacts on fish production in the Kemano River are not predictable at this time with any degree of certainty. The expectation is that current fish production can be maintained.

On the general subject of diseases and parasite transfer, there was no substantial concern identified to warrant objection to the Nanika Diversion. Some long term monitoring has been suggested.

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------ 1986. "Water Transfers in the Prairie Provinces; A 1985 Inventory". Water Planning and Management Branch, Environment Canada, REgina. 69 pp. (13b)

This inventory and classification of existing water transfers in the Western and Northern Region was written to better inform the public and resource managers. Elements included in this inventory, along with project maps and drawings, are flow volumes, contributing and receiving streams, purpose, implementation date, responsible agency, reported impacts and relevant information sources.

Criteria for a water transfer to be included in this inventory:

(1) minimum mean annual flow or volume diverted $0.75 m^3/s$ or $15,000 dam^3$

(2) no return to stream of origin (or parent stream) within 25 km of point of diversion; no exit to sea within 25 km of point of diversion.

The inventory has been developed in consultation with federal and provincial officials and published by Inland Waters Directorate.

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Arai, H.P. and Mudry, D.R., 1983. "Protozoan and Metazoan Parasites of Fishes From the Headwaters of the Parsnip and McGregor Rivers, British Columbia: A Study of Possible Parasite Transfaunations". Can. J. Fish. Aquat. Sci. 40(10): 1676-1684. (14)

Results are presented on a study to determine the possible extent of parasite transfaunation across the Continental Divide as a result of a proposed water diversion in northeastern British Columbia. Fish populations in the headwater areas of the McGregor River (Pacific drainage) and of the Parsnip River (Arctic drainage) were sampled during August - November 1976 and during June - September 1977. Eighty-eight species or higher taxonomic groups of parasites were recovered from 1489 host specimens, representing 13 genera and 20 species of fishes.

Based in part on these studies, the British Columbia Hydro and Power Authority, in a public announcement, suspended engineering studies of the proposed diversion.

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Arthur, J.R. L. Margoilis, and H.P. Arai. 1976. "Parasites of fishes of Aishihik and Stevens lakes, Yukon Territory, and Potential Consequences of Their Interlake Transfer Through a Proposed Water Diversion for Hydroelectrical Purposes." J. Fish Res Board Can. 33: 2489-2499. (15)

Forty-six species of parasites (14 Protozoa, 7 Monogenea, 7 Digenea, 8 Cestoda, 2 Acanthocephala, 4 Nematoda, 3 Copepoda, and 1 Hirudinoidea) were recovered from 383 specimens of 8 species of fishes collected from Aishihik and Stevens Lakes, Yukon Territory, during the summer of 1973. Four species, Chloromyxum dubium. C. esocinum Sphaetrospora cristata (all Protozoa), and Crepidostomum metoecus (Digenea) are reported for the first time from North America.

Aspects of the systematics and distribution of several species are discussed and the following new synonymies recognized: Tetraonchus rauschi with T. borealis (Monogenea), Cystidicola stigmatura with C. farionis and Raphidascaris canadensis with R. acus (both Nematoda).

Substantial differences in the parasite fauna of Aishihik and Stevens Lakes are noted: the possible consequences of the introduction of species of potential economic and pathogenic importance e.g. Henneguya zschokkei, Hexamita salmonis (both Protozoa), Discocotyle sagittata (Monogenea) Neoechinorhynchus rutili (Acanthocephala), and

Triaenophorus nodulosus (Cestoda) into new areas as a result of the proposed diversion of Stevens Lake (Yukon River system) into Aishihik Lake (Alsek River system) are discussed.

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Baxter, R.M. and Glaude, P., 1980. "Environmental Effects of Dams and Impoundments in Canada: Experience and Prospects." Can. Bull. Fish. Aquat. Sci. 205, 34 pp. (16)

Although dams and reservoirs have contributed immeasurably to the well-being of Canadians they may have side effects which may be detrimental to the environment and to human welfare. In this report, the authors survey the environmental consequences that have ensued from dam construction and the impoundment of water in Canada in the past, and attempt to alert environmentalists and engineers to the types of problems that may be associated with such activities in the future.

Some of these effects are immediate, direct, and obvious, such as the loss of resources by flooding, interference with the passage of fish, and environmental damage and pollution as a result of construction activities. Others may manifest themselves only over a period of

time, such as changes in water chemistry and modification of the new shoreline. This last is likely to be of particular importance in reservoirs on permafrost. Large impoundments may influence the climate in their vicinities and sometimes induce earthquakes. Still other consequences follow from the mode of operation of the reservoir. Low-level discharge through turbines may radically alter the temperature regime in the stream below. The induction of an unnatural seasonal pattern of water level fluctuation may lead to the formation of a virtually barren drawdown zone around the reservoir, and induce geographical and ecological downstream impacts, sometimes at great distances.

Many of these effects act in various and sometimes opposing ways on the living organisms in the reservoir and the stream so that the ultimate biological consequences often cannot be confidently predicted.

It is sometimes difficult to reconcile the interests of those who stand to benefit from a given project and the interests of others who are likely to suffer a loss from it. This conflict is particularly acute when the project affects communities of native peoples following a traditional way of life. Such fragile societies are likely to be gravely disrupted unless particular care is taken.

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Berkes, F., 1982. "Preliminary Impacts of the James Bay Hydroelectric Project, Quebec on Estuarine Fish and Fisheries." Artic 35(4):524-530. (17)

Flow alterations related to hydroelectric development have affected both the fish stocks and the Cree Indian subsistence fishery in the lower LaGrande River, northern Quebec. Evaluated against several years of baseline data, the initial biological impact of the project on fish populations, mostly whitefish (Coregonus clupeaformis) and cisco (C. artedii), appeared to be relatively small. Nevertheless, fishing activity in the lower river and the estuary largely ceased from 1979 to 1981, due to physical modifications of traditional fishing areas and other social and economic effects related to the hydro project. Some fishermen modified their methods and continued harvesting in the affected area, but others abandoned the affected area and fished lakes and rivers along the recently constructed road network. It is concluded that earlier impact assessments fell short of predicting these impacts.

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Bodaly, R.A., Erickson, R.N. and Fudge, R.J.P., 1980. "Pre- and Post-Impoundment Experimental Fish Catches, Southern Indian Lake, Manitoba 1972 - 1979". Can. Data Rep. Fish. Aquat. Sci. No 201, 78 pp. (18)

Experimental fishing by graded mesh gill net gangs was conducted in southern Indian Lake, Manitoba, in 1972, 1974, 1975 and 1976, prior to the impoundment and diversion of the lake, and in 1978 and 1979, after impoundment and diversion. Ten species of fish were captured: lake whitefish Coregonus clupeaformis, walleye Stizostedion vitreum, northern pike Esox lucius, white sucker Catostomus burbot Lota lota, cisco, probably a mixture of Coregonus artedii commersoni, longnose sucker Catostomus catostomus, Lesueur, and Coregonus nigripinnis, perch Perca flavescens, and goldeye Hiodon alosoides. Data is presented in tabular form, on the numbers of each species captured in each mesh size panel of each gill net gang set.

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Bodaly, R.A., Hecky, R.E. and Fudge, R.J.P., 1984. "Increases in Fish Mercury Levels in Lakes Flooded by the Churchill River Diversion, Northern Manitoba." Can. J. Fish. Aquat. Sci. 41:682-691. (19)

Reservoir creation has often been inferred as a cause of elevated fish mercury concentrations. Increases in fish muscle mercury levels, occurring coincidentally with flooding, are documented for three lakes affected by the Churchill River diversion for which pre- and post-impoundment data were available. For example, in northern pike (Esox lucius) and walleye (Stizostedion vitreum vitreum) muscle mercury levels from Southern Indian Lake, which was increased in surface area by 21% by flooding in 1976, increased from baseline values of 0.2-0.3 $ug \cdot g^{-1}$ prior to flooding to 0.5-1.0 $ug \cdot g^{-1}$ in 1978-82. Muscle mercury levels from predatory species (northern pike and walleye) from all 10 lakes tested in the Churchill, Rat and Burntwood valleys flooded by the Churchill diversion are near to or exceed the current export marketing limit of 1.0 $ug \cdot g^{-1}$. Because mercury levels in fish from nearby unflooded lakes have not shown recent increases, atmospheric fallout of the metal does not appear to be the cause of the problem. Also, there are no known industrial sources of mercury in the area and no agricultural activity. Post-impoundment mercury levels in predatory fish appeared to be related to the flooded terrestrial area compared with pre-impoundment lake area. They were highest (1.15-2.90 $ug \cdot g^{-1}$) in Rat and Notigi lakes, which were increased in surface area by 282%, lower (0.60-1.53 $ug \cdot g^{-1}$) in lakes immediately below Notigi Reservoir, increased in surface area by 31-37%, and lowest (0.45-1.03 $ug \cdot g^{-1}$) in Southern Indian and Wuskwatim lakes, increased in surface area by 13-21%. Fish mercury levels responded quickly to impoundment, increasing noticeably within 2-3 yr.

Declines in mercury concentrations had not, in general, taken place within 5-8 yr of impoundment, with the exception of lake whitefish (Coregonus clupeaformis) from Southern Indian Lake. It is hypothesized that observed fish mercury level increases were due to the bacterial methylation of naturally occurring mercury found in flooded soils.

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Bodaly, R.A. Johnson, T.W.D., Fudge R.J.P. and Clayton, J.W., 1984. Collapse of the Lake Whitefish (Coregonus clupeaformis) Fishery in Southern Indian Lake, Manitoba, following Lake Impoundment and River Diversion." Can. J. Fish. Aquat. Sci. 41:692-700 (20)

The lake whitefish (Coregonus clupeaformis) fishery of Southern Indian Lake (SIL) has undergone a general collapse since lake impoundment and Churchill River diversion in 1976. The fishery was substantial from its inception in 1941, with a mean annual whitefish catch of 333 500 kg over the 3 decades prior to lake impoundment. The whitefish catch prior to impoundment was composed almost exclusively of light colored, export quality fish that were only lightly parasitized with the muscle cysts of Triaenophorus crassus. The market quality of the catch was maintained by selective fishing of certain lake basins and avoiding areas of the lake that were known to produce lower quality fish. Catch per unit of effort on traditional fishing grounds declined soon after impoundment to about one-half preflooding levels. Total catches were maintained at or near preimpoundment levels by major increases in total effort until 1982, when the whitefish catch fell to about one-third of its preimpoundment mean. Fishermen also responded to declines in catch per unit of effort on traditional fishing grounds with a major geographic shift of effort into areas formerly avoided. As a result, darker colored, continental quality whitefish comprised from 12 to 72% of the summer catch in the 4 years following impoundment. Dark whitefish are less marketable because of color and because of higher rates of Triaenophorus infestation. The mean Triaenophorus cyst count in shipments has increased markedly since impoundment and the lake was reclassified from export to continental classification in 1982. Catch declines on traditional fishing grounds apparently reflect the emigration of fish to other SIL basins and/or to adjoining water bodies. Prior to lake impoundment, there were significant differences in glycerol-3-phosphate dehydrogenase allele frequencies from whitefish samples taken from four basins of SIL and an adjacent unconnected lake, but these differences were absent after impoundment. It is hypotesized that these stock redistributions were triggered by physical changes in SIL after lake impoundment.

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Bodaly, R.A., Rosenberg, D.M., Gaboury, M.N., Hecky, R.E., Newbury, R.W. and Patalas, K., 1984. "Ecological Effects of Hydroelectric Development in Northern Manitoba: The Churchill-Nelson River Diversion", in "Effects of Pollutants at the Ecosystem Level", SCOPE, John Wiley and Sons Ltd. p. 273-309 (21)

Planning for hydroelectric development on the Churchill and Nelson rivers began almost two decades ago and major dams, diversions and power stations were operational by 1977. Extensive pre-development ecological studies and environmental impact predictions were carried out. Studies on selected portions of the affected area encompassing the physical, chemical and biotic levels have continued to the present, using data from the predevelopment period as ecosystem baselines. Emphasis has been on the impact of aquatic eological changes on the harvest of fish by man.

This study of the ecological effects of the Churchill-Nelson diversion emphasized the response of Southern Indian Lake to impoundment and diversion. Therefore, the study treats Southern Indian Lake in detail and then outlines the physical changes resulting from Churchill River diversion in lakes along the Churchill valley and the diversion route, and briefly describes the results of some biological studies in Notigi Lake. The study also includes an outline of the downstream effects on Cross Lake because, although the lake is located outside of the immediate Churchill River diversion area, it demonstrates the effect that lowered water levels can have on fisheries.

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Boothroyd, P.N., 1983. "Effect of the Churchill River Diversion on Waterfowl Use of the Lower Churchill River, Manitoba" in "Resources and Dynamics of the Boreal Zone". Assoc, Can. Univ. for Northern Studies. p. 443-457 (22)

The effect of reduced flows resulting from the Manitoba Hydro Churchill River diversion project on waterfowl use of the Lower Churchill River was investigated in 1978 and 1979. Significant changes in river morphology were documented with aerial photography. Densities of waterfowl using areas on and away from the river in 1978 and 1979 are compared to prediversion waterfowl densities in the study area and to regional population trends. Altered flow regimes appear to have indirectly resulted in reduced use of the Churchill River by breeding ducks and geese. Low nesting effort by Canada geese was apparent on the Churchill River in 1979. It is suggested that this may be attributed to reduction in availability of attractive breeding habitat. Recommendations are made concerning further studies and regulation of Churchill River flows.

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Boucher, R., Wickham, P. and Roy, D., 1984. "Modifications Observées sur La Grande Rivière en aval du Réservoir de LG 2". Société d'Energie de la Baie James, Direction Ingeniere et Environment, Quebec. 109 pp. (23)

Five reservoirs had to be constructed for the first phase of the La Grande complex in Northern Quebec, including the LG 2 reservoir, the furthest downstream on the La Grande River. Filling of the reservoir and operation of the power station of the same name markedly altered water and flow conditions in the La Grande River and its estuary. Because there is a Cree village close by and fish from the estuary forms an important part of the natives' diet, the Société d'énergie de la Baie James (SEBJ) has accorded particular attention to this area. Several reports have been written defining the various possible repercussions, suggesting corrective measures, and detailing the observations made in this section of the La Grande River.

To facilitate comprehension of the chain of events, it was felt important to summarize in one document all the studies and projects which have been undertaken and their results. This document has two parts. The first (Wickham and Roy, 1984) deals with the evaluation of the repercussions of the interruption of river flow when the LG 2 reservoir was filled, and with the supposed regularization of flow subsequently. The various possible corrective measures are discussed, as are the reasons for choosing those eventually decided on. A brief analysis of the physical and chemical changes observed in the water from 1973 to 1983 is included. The second part, adds information relative to aquatic fauna (zooplankton, benthos, fish) for the same period (text in french).

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Bridger, K.C., 1978. "The Ogoki Diversion: Reservoir, Downstream, Diversion Channel and Receiving Water Body Effects." unpub. M.A. thesis, University of Waterloo, Ontario. (24)

The engineering feasibility of transbasin water diversions in northern Ontario has been thoroughly investigated. The probable ecological and social effects of such schemes, however, are poorly understood. In this study, the biophysical and socioeconomic effects of the small-scale Ogoki River Diversion (1943) in the Precambrian topography of northwestern Ontario are examined in reservoir, downstream, diversion channel, and receiving waterbody areas. Project compatibility with other study-area resource uses is assessed from the perspective of affected occupational groups. The study attempts to generate insights into the probable effects of future water diversions and recommends measures to heighten management sensitivity to the ramifications of such projects.

In the Ogoki Reservoir, conversion from a riverine to a lacustrine ecosystem greatly enlarged aquatic and shoreline habitat. Shallow inundation and other reservoir features enhance aquatic productivity. Winter water-level drawdowns, however, adversely affect littoral community stability. The Ogoki Reservoir area is sparsely developed. Two sportsmen outfitters operating 6 reservoir fly-in camps consider excellent fishing and moose hunting to override aesthetic impairment, fish-tackle snagging, and shoreline access and navigation difficulties. A wild river reach has been lost, however, and resource-use opportunities in large areas of the reservoir are precluded by wood debris.

The downstream Ogoki River is characterized by flow prevention which exposes fast-water habitat and creates long, stagnant river reaches. Periodic flow releases from the Waboose Dam, however, perpetuate instability in downstream aquatic ecology. High water reduces hunting and fishing success, and camp flooding and equipment losses have occasionally occurred. Generally, flows and water levels are moderate enough for successful outfitting operations at the 8 downstream fly-in camps.

Greatly enlarged diversion-channel flows initiated extensive Little Jackfish River bank erosion creating severe siltation and turbidity stresses in Ombabika Bay. Initially, high erosion rates adversely affected Ombabika aquatic productivity and fish reproduction. It is difficult to assess recovery in the bay, however, under a seasonally maintained but much reduced turbidity stress, particularly since effects are compounded by fish exploitation and prolonged log driving. Lake Nipigon outfitters assert the diversion has reduced Ombabika recreational amenities.

In receiving water bodies, higher long-term Lake Nipigon water levels have induced intensive localized shoreline erosion, particularly at one inhabited and several abandoned Indian reserves bordering the lake. In 1973, Ontario Hydro riprapped the Gull Bay Indian Reserve shoreline. Elsewhere on Lake Nipigon, small-scale property losses, slight commercial fishing and outfitting impediments, and archaeological losses have occurred. The Ogoki Diversion marginally increases Great Lakes water levels though the effect is counteracted by Chicago and Welland Canal withdrawals.

In an overall evaluation, the inconvenience and difficulties created by the diversion appear of relatively minor significance when compared to project economic benefits in excess of 170-million dollars achieved through hydroelectric electric power generation.

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Bruce, W.J., and K.D. Spencer. 1979. "Mercury levels in Labrador fish, 1977-78". Can. Ind. Rep. Fish. Aquat. Sci. 111: 12 pp. (25)

This report describes a study undertaken to delineate mercury levels in Labrador's freshwater and anadromous fishes. The primary objective was to examine mercury content in fish in the area of the Smallwood Reservoir.

Approximately 6000 tissue samples representing fourteen fish species from Labrador were analyzed for mercury content. Mean mercury values were highest in the two fish-eating species, lake trout and northern pike, where mean mercury values exceeded 0.5 ppm. Mean mercury values for whitefish and suckers were generally less than 0.5 ppm as was also the case for brook trout. Resident or landlocked populations of Arctic char and Atlantic salmon displayed higher mean mercury values than their ocean counterparts. Anadromous rainbow smelt showed mean mercury values slightly greater than 0.2 ppm.

The highest mercury values were found in fish from the Smallwood Reservoir and waters of the Churchhill River downstream of the Lobstick Control Structure. Evidentally, flooding of this reservoir has accelerated the normal leaching rate of mercury into the aquatic environment.

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Davies, L.B. and Shumuk, Y., 1979. "Prediction of Some Effects of a Major Interbasin Diversion by use of a Flow-Sediment Model" in "River Basin Management," Vol. 1. Canadian Society for Civil Engineering. pp. 211-232. (26)

The McGregor River Diversion Project, which was studied by B.C. Hydro and Power Authority in 1976 and 1977, would require the diversion of most of the flow of the McGregor River across a natural divide into the Parsnip River. Environmental considerations indicated that detailed studies were necessary to assess the effects of the diversion on river fisheries, and on wildlife feeding and nesting areas in the Parsnip River Valley, which in turn required an assessment of the expected morphological changes in the valley. The upstream 60 km of the valley is underlain by 15 m of sandy silt interbedded with peat, and deposits of alluvial gravel. A computer model was used to simulate the erosional and depositional processes along the diversion channel route.

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Day, J.C., 1985 "Canadian Interbasin Diversions". Inquiry on Federal Water Policy, Research Paper #6, Environment Canada, Ottawa K1A OH3. 110 pp. (27)

Canadians have long experience in interbasin water transfer on which to base judgements concerning the desirability and management of future projects. Enormous progress was made in planning hydroelectric diversions over the past four decades. From an initial emphasis on engineering, geotechnical, and economic concerns in the Ogoki, Long Lake, and the first phase of the Kemano projects, gradually biophysical and social questions received increased attention and more sensitive treatment in the Churchill-Nelson, James Bay, and Kemano completion projects. But more effective institutional arrangements are needed to reconcile federal and provincial management responsibilities, particularly in the interjurisdictional setting of shared river basins. Before initiating any large-scale diversions of Arctic waters, studies are needed to define potential effects on climate and marine environments. The potential for detrimental change due to biota transfer when major drainage divides are crossed also requires investigation. Enormous overbuilding of diversion-related hydroelectric capacity has been costly to the Canadian public. More equitable treatment of Native groups negatively affected by diversions is a major need in future projects. The long-standing Canadian federal policy which has consistently opposed water export without supporting evidence needs to be rethought. These and other related issues are discussed in this paper.

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Day, J.C., Bridger, K.C., Peet, S.E. and Friesen, B.F., 1983. "Experience with Diversions into the Great Lakes: The Ogoki and Long Lake Projects." presented at the March 1983 "Symposium on Diversion of Great Lakes Water: Critical Resources - Critical Issues", West Michigan, Kalamazoo 49008. (28)

Biophysical and socioeconomic effects are identified in reservoir, downstream, division channel, and receiving water body areas. Overall, the projects have been socially useful, especially from the perspective of hydroelectric, log driving, and economic development benefits. However, selected socially inequitable aspects of the projects and other problems related to erosion, turbidity, multiple resource use, failure to clear trees, and heritage resource losses are identified. Suggestions for planning similar projects are presented.

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Dickson, I.W., 1975. "Hydroelectric Development of the Nelson Rivers System in Northern Manitoba" J. Fish. Res. Bd. Can. 32(1): 106-116 (29)

The proposal by Manitoba hydro to divert the Churchill River (completed 1976) at Southern Indian Lake to the Nelson River via the Rat-Burntwood rivers is discussed. Combined flows of the Churchill and Nelson rivers would generate more than 7 million kw at 14 power generating sites along the Nelson River system. Regulation of Lake Winnipeg is required to provide additional storage to augment flows in the Nelson River.

Impacts to beaches and marshes and related implications to recreation and wildlife uses are important aspects of Lake Winnipeg regulation. Long-term ecological changes to Lake Winnipeg may be significant. The level and flow pattern of other waters at the outlet from Lake Winnipeg (Outlet Lakes) will also be altered by regulation. Environmental impacts attributed to this altered regime of level and flow are likely to be of lesser significance than impacts in other areas. Life styles and cultural values of residents in the remote Cross Lake community may be affected by the project.

Diversion of 850 m^3/s from the Churchill to the Nelson River may reduce flows which have historically ranged from 580 m^3/s to 2,605 m^3/s (mean of 963) to minimum winter and summer flows of 43 m^3/s and 14 m^3/s, respectively. While socio-economic considerations and related resource implications appear to be of relative minor importance, altered levels, flows, and associated ice regime may be expected to significantly alter the aesthetic qualities of the river. Raising Southern Indian Lake level may cause major changes to the appearance of the landscape and the utilization of associated resources. Socio-economic implications of flooding may be significant.

Storage and release of waters from impoundments along the Rat-Burntwood diversion route will significantly alter the characteristics of the land-water interface. Flows increased from 113 m^3/s to 963 m^3/s and flooding will have a major impact on availability and utilization of associated resources. Notigi Lake control for Churchill River diversion will cause flooding of about 40,500 hectares or approximately 156 square miles. Additional flooding of approximately the same area below the Notigi Control can be anticipated following diversion and the development of Wuskwatim and Manasan sites on the Burntwood River.

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Duthie, H.C. and Ostrofsky, M.L., 1975. "Environmental Impact of the Churchill Falls (Labrador) Hydroelectric Project: A Preliminary Assessment". J. Fish. Res. Bd. Can, 32: 117-125. (30)

The Churchill Falls hydroelectric project in western Labrador involved the creation of reservoirs totalling 6650 km^2 in area and the diversion of two rivers: the Churchill and the Naskaupi. A considerable area of forest and muskeg was inundated. The original feasibility studies for the project concentrated on a cataloging of fish and wildlife. Downstream effects of flow regulation were considered. Preliminary findings show little evidence for humification or oxygen deficiency even in newly flooded areas, but conductivity and many dissolved ions have increased. Populations of both phytoplankton and zooplankton have generally increased and changed qualitatively with impoundment, particularly in shallow water. The primary productivity of the phytoplankton has increased significantly in flooded areas.

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Geen, G.H. and Andrew, F.J., 1961. "Limnological Changes in Seton Lake Resulting from Hydroelectric Diversions". Int. Pacific Salmon Fish. Comm., Progress Rep. No. 8. 73 pp. (31)

Limnological changes occurring in Seton Lake and Seton Creek as a result of hydroelectric diversions from Bridge River and Cayoosh Creek into Seton Lake were investigated to provide information that would be of value in assessing effects of other proposed diversions in the Fraser River system. The changes included reduced temperatures and dissolved mineral content and increased turbidity and flushing rate. Plankton production appeared to be greatly reduced, primarily because of a pronounced increase in turbidity.

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Geen, G.H., 1974. "Effects of Hydroelectric Development in Western Canada on Aquatic Ecosystems." J. Fish. Res. Bd. Can. 31 (5): 913-927. (32)

The effects of some existing and proposed hydroelectric developments on lakes and rivers of Western Canada are considered. There are few pre- and post-impoundment studies from this region on which to base generalizations, although the changes in species composition and water chemistry following impoundment of rivers and lakes reported thus far are comparable to those observed in other areas at similar latitudes.

Few data are available which permit prediction of thermal regimes in newly formed reservoirs, particularly in view of the turbid nature of some inflows to reservoirs. Several hydroelectric developments have blocked or impeded migrations of economically important fish and appear likely to produce a number of downstream changes in water temperature or composition, the effects of which are often speculative. More studies of the effects of altered temperature and flow regimes, reduced turbidity, and gas supersaturation are required.

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Golubev, G. 1978. "Environmental Issues of Large Interregional Water Transfer Projects" in "Water Development, Supply and Management" Vol. 6 Pergamon Press, Oxford, New York. pp 177-186. (33)

The first part of this paper involves a general discussion of two principal questions related to the environmental issues of large water transfers:

(1) How does one evaluate efficiency of a project incorporating environmental issues which are sometimes not measureable?

(2) How does one predict environmental consequences of large water transfer projects?

The second half of this paper discusses the environmental issues of large interregional water transfer projects in the USSR. Nine figures are included in the text.

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Golubev, G., Grin G., Melnikova, G. and Whetstone, G. 1978. "Bibliography on Interregional Water Transfers" in "Water Development, Supply and Management" Vol. 6. Pergamon Press, Oxford, New York. pp. 187-210. (34)

A bibliography on interregional water transfers is presented. Sources have been selected which were related directly to problems and schemes of interregional (or large-scale) water transfers.

The bibliography contains 502 entries and as a rule, short notes have not been included. The majority of the publications are in languages of the Latin alphabet; the remainder are in the Cyrillic alphabet (Soviet papers), with corresponding translations into English.

As a considerable amount of publications are included in the list, sections were established according to items. Each section is listed alphabetically according to authors. The following sections are listed: General, Regional, Economy, Environment, Hydrology, Technology, Methodology and Water Management, and Politics and Law. The Regional section has been sub-divided into continents, plus the USSR which is situated in two continents.

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Guilbault, R.A., Gummer, W.D. and Chacko, V.T., 1979. "The Churchill Diversion: Water Quality Changes in the Lower Churchill and Burntwood Rivers". Water Quality Interpretative Rep. No. 2, Inland Waters Directorate, Environment Canada. (35)

In June of 1976, Manitoba Hydro commenced operation of the Churchill River diversion, which is part of the Churchill-Nelson Hydroelectric Development Scheme. A statistical analysis of data obtained from a water quality monitoring network maintained in northern Manitoba by the federal Water Quality Branch indicates changes in the quality of both the lower Churchill and Burntwood Rivers. On the lower Churchill there is evidence of increase in turbidity, colour, total inorganic carbon, total phosphorus, hardness, calcium and aluminum. On the Burntwood River there is evidence of a decrease in calcium concentration and increases in total phosphorus, potassium and aluminum concentrations. A large number of parameters showed a change in their variability.

The magnitude and cause of the water quality changes cannot be quantified precisely, since the data base used was not collected with this purpose in mind. Many of the results of this study are in agreement with the general predictions made in 1975 by the Lake Winnipeg, Churchill and Nelson Rivers Study Board.

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Hecky, R.E. and Guildford, S.J., 1984. "Primary Productivity of Southern Indian Lake before, during and after Impoundment and Churchill River Diversion." Can. J. Aquat. Sci. 41:591-604. (36)

The primary productivity of seven regions of Southern Indian Lake and neighboring Wood Lake was measured during open-water seasons from 1974 to 1978. The lake had regional differences in chlorophyll concentrations and daily rates of integral primary production in 1974 and 1975 prior to impoundment. Regions receiving Churchill River flow tended to have higher chlorophyll concentrations and production rates

than those regions marginal to the flow. Impoundment of the lake resulted in higher efficiencies of primary production in all regions, as indicated by higher light-saturated rates of carbon uptake per unit chlorophyll and by higher initial slopes of the hyperbolic light response relation of the phytoplankton.

Many large basins of the lake had light penetration reduced by high concentrations of suspended sediment from eroding shorelines, while other areas had relatively unchanged light penetration. The increased efficiency of carbon fixation per unit chlorophyll resulted in higher rates of integral production in those regions where light penetration was not greatly affected. Daily rates of integral primary production in lake regions where light penetration had decreased markedly were not significantly different after impoundment because efficiencies of light utilization were higher. Comparison of the mean water column light intensities for those turbid regions with the values of I_k (light intensity at the onset of light saturation) for phytoplankton indicated that these turbid regions are now light deficient on average. Phosphorus deficiency, as indicated by alkaline phosphatase activity per unit ATP, which was present before impoundment, has been eliminated as the mean water column light intensity declined below 5 $mEinsteins \cdot m^{-2} \cdot min^{-1}$. The light environment of a new reservoir can be a significant determinant of integral production, and predicting the consequences of impoundment on phytoplankton production requires accurate prediction of the light environment.

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Hecky, R.E. and G.K. McCullough. 1984. "The Landsat imagery of Southern Indian Lake: a Remote Perspective on Impoundment and Diversion." Can. Tech. Rep. Fish. Aquat. Sci. 1266: 20 p.p. (37)

Seven colour Landsat images are reproduced, showing Southern Indian Lake from 1973, three years before impoundment, until the present. They provide a visual history of some of the major physical changes which have occurred in the lake. Increases in lake turbidity under high water conditions in 1975 and impoundment in 1976 which have been quantified with on-lake data are readily apparent in the imagery. The altered pattern of turbidity within the lake illustrates the nature of bank materials being eroded and circulation patterns of the lake. Black and white Landsat images provide direct evidence of the pattern of ice break-up on the lake and how it has changed with diversion. Newly flooded areas are readily apparent, as are dewatered lake areas on the lower Churchill River caused by river diversion. Satellite imagery can provide spatially extensive and continuous data on these large systems which are unavailable by any other means.

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Kellerhals, R., Church, M. and Davies, L.B., 1979. "Morphological Effects of Interbasin River Diversions". Can. J. Civ. Eng. (6): 18-31. (38)

Data on the morphological effects of 11 Canadian interbasin river diversions are presented and some of the more fully documented cases are discussed and illustrated. A classification of diversion routes is suggested and procedures for evaluating the morphological effects in each classification are proposed.

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Lau, Y.L., Krishnappan, B.G. and Engel, P., 1984. "Effects of Diversions on River Regime". National Water Research Institute, Burlington, Ontario. 19 pp. (39)

A review has been made of literature related to physical effects of river diversion, in particular, the effects on river regime. The possible effects of diversions on the receiving and donor streams are discussed and methods which are presently available for predicting some of these effects are briefly outlined. Research needs which are required to produce satisfactory prediction methods are discussed.

A list of annotated bilbliography of diversion-related literature is included with this report.

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Lindsey, C.C., 1957. "Possible Effects of Water Diversions on Fish Distribution in British Columbia". J. Fish. Res. Board Can. 14: 651-668. (40)

The known distributions of freshwater fishes in drainages of the British Columbia mainland are summarized, including those of five species not previously recorded from the province. The continental divide forms a break in fish distribution; 35 of the 57 species on the Pacific slope in B.C. do not occur in the Mackenzie or Yukon River drainages of the province, and 11 of the 33 species in the latter area occur nowhere on the Pacific slope. Some proposed water diversions for hydroelectric development would cross the continental divide, and are likely to produce striking changes in fish distribution. A proposed Liard-Stikine diversion would probably introduce several species, including trout, into the upper Liard River, and several other species, including northern pike into the Stikine River. A proposed Peace-Fraser diversion would introduce into the Fraser River arctic grayling, and possibly several other species including northern pike. Other proposed diversions are discussed, and their probable

affects on fish distribution are listed. Any diversion introducing pike into waters supporting Pacific salmon is liable to be economically harmful, as pike are voracious fish-eaters. Pike are also vectors of Triaenophorus tape-worm, which has been found in Alaska to encyst in the flesh of Pacific salmon in a watershed inhabited by pike.

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McCullough, G., 1981. "Water Budgets for Southern Indian Lake, Before and After Impoundment and Churchill River Diversion, 1972-1979". Can. Manuscr. Rep. Fish. Aquat. Sci. No. 1620. 26 pp. (41)

Water budgets have been determined for southern Indian Lake in northern Manitoba, for the whole lake and for individual basins, to quantify changes in patterns of flow and water exchange times due to impoundment and diversion of the Churchill River. Calculated natural exchange times for various basins of southern Indian Lake vary from 0.012 to 4.2 years. The budgets indicate that in basins along the path of the Churchill River both before and after diversion exchange times are not greatly changed. In those basins isolated from the Churchill River both before and after diversion exchange times are doubled due to increased lake volume. In two northern basins away from which 80% of the Churchill River flows have been diverted exchange times are increased by an order of magnitude. In South Bay, through which the Churchill River has been newly diverted, the gross exchange time has been decreased by two orders magnitude.

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McLeod, G.D., 1979. "McGregor River Diversion, Fraser River Water Temperature Study" in "River Basin Management", Vol. I, Canadian Society of Civil Engineering. pp 180-195. (42)

This paper describes the studies carried out by the British Columbia Hydro and Power Authority to assess the effects of diversion of the McGregor River from the Fraser River system on the summer water temperature regime of the Fraser River from the confluence of the McGregor River downstream to Hope, a distance of about 720 km. The results of this study were used to assess, in part, the effects of the diversion on the salmon fishery in the Fraser River system.

The results of this study indicate that the increase in summer water temperatures of the Fraser River due to diversion would be greatest just above the confluence of the Quesnel River where the expected average summer water temperature would be about 1.0°C higher than before diversion. At Hope the expected mean summer water temperature

would be about 0.5°C higher than before diversion. Tributary inflows from the Quesnel River to Hope, which are generally cooler than the Fraser River flows, would reduce the effects of the diversion on the water temperature regime of the Fraser River.

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Marier, V., 1984. "Environmental Monitoring of the La Grande Hydro-electric Complex". Environment Canda, James Bay and Northern Quebec Office. 141 pp. (43)

This study includes a summary of the results obtained by the La Grande complex ecological monitoring network, together with comments on the biophysical monitoring.

The study begins with a bibliographical survey of the documents published on the subject, particularly since 1980-81. Following a review of the relevant documents and consultation with agencies associated with the project, a synthesis has been prepared of the information acquired by the environmental monitoring with respect to the sectors affected by the hydroelectric developments.

This document contains information on the geomorphological, geological, hydraulic and oceanographic monitoring of the three major regions affected: the region of the La Grande River, the region of the Caniapiscau and Koksoak Rivers and that of the Eastmain and Opinaca Rivers. A separate chapter has been devoted to two specific parameters, mercury and acid rain. A relatively exhaustive bibliography is appended to the document; it offers a good source of information on the specific involvement of various agencies and resource people and some indication of the scope of the studies performed on this region.

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Micklin, P.P., 1985. "The Vast Diversion of Soviet Rivers." Environment 27(2): 12-25 (44a)

Few projects to modify the environment provoke more heated debate than schemes to divert water from one basin to another. In the United States, grandoise proposals to move water from the Pacific Northwest or the lower Mississippi River to the arid Southwest have been touted and abandoned. In China, an ambitious south-north diversion of Yangtze water is being planned. After decades of argument, the Soviet Union has decided to go ahead with major north-south transfers. Rapid implementation of Siberian transfers is considered imparative because of what is widely viewed as a worsening water supply situation in Kazakhstan and Central Asia.

Particular emphasis has been placed on understanding the major deleterious ecological and environmental consequences of the project as a basis for minimizing damage. The effort has been massive, reportedly involving more than 120 institutions. Drawing on studies last year in Moscow, this article reports on the status and prospects for the Soviet schemes.

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Mundie, J. H. and Bell-Irving, R., 1986. "Predictability of the Consequences of the Kemano Hydroelectric Power Proposal for Natural Salmon Populations." Can. Wat. Res. J. 11 (1): 14-25. (44b)

The Aluminum Company of Canada, Limited (Alcan) has proposed completion of its hydroelectric developments to increase aluminum smelting capacity in north-central B.C. The project was started in 1950 and included the Kenney Dam on the Nechako River in the Fraser catchment area, the creation of the Nechako Reservoir, and the construction of facilities for generating power at the Kemano River on the west coast. Completion of development (Kemano Completion Proposal), at a cost of over $2 billion, would divert 84 percent of the initial mean annual discharge of the Nechako River, and 62 percent of the mean annual discharge of the Nanika River in the Skeena catchment area, to the Kemano River. The proposal offers discharges that are intended to protect Pacific salmon stocks, or, where this is not possible mitigation of losses. This paper identifies the more obvious effects of abstraction and regulation on salmon populations and their habitat. These include interference with migration of adults, changes in the quality of spawning gravel, imposition of stress on all stages of the fish from high total gas pressures and from alterations in ambient temperature, changes in the composition of the total fish community, changes in the production and availability of food, stranding of fish, weakening or loss of cues for homing, and increased exposure to predation from fish and birds. A major difficulty in trying to relate effects to salmon populations lies in distinguishing fish numbers as determined by habitat effects, from numbers determined by the level of recruitment to the rivers as a result of exploitation by the fishery. Three approaches to the problem are experimental design of impact assessment, modelling changes of discharge and salmon habitat, and analysis of case histories of regulated discharge. The last seems to be the most instructive per unit of effort required. As an approximation to obtaining replication of treatment effects, and to judge the reliability of prediction of effects of flow regulation, case histories of regulated salmonid rivers were examined. It was found that negative effects out-numbered positive ones, that prediction was usually incorrect, and that, even where flow regulation was implemented with the express intention of increasing numbers of salmonids the results fell short of expectations. On this evidence it appears that the

outcome of a development as demanding of water as Kemano completion is difficult to predict in precise quantitative terms and carries some risk for natural populations.

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Newbury, R.W. and McCullough, G.K., 1983. "Shoreline Erosion and Re-establishment in a Permafrost-Affected Impoundment" in Permafrost Fourth International Conf., Proceedings. Nat. Academy Press, Wash. D.C. ISBN 0-309-03435-3. (45)

In 1976, an 850 m^3/s river diversion was constructed through 300 km of permafrost-affected landscape in northern Manitoba. The diversion was accomplished by raising the level of a 1,977 sq km riverine lake on the Churchill River (Southern Indian Lake) until the water spilled across a terrestrial drainage divide into a series of small valleys tributary to the Nelson River. Over 400 sq km of permafrost-affected backshore area surrounding the lake were flooded. The mean annual temperature in the Southern Indian Lake region is -5C. Three repeated phases of shoreline erosion in permafrost materials were observed; melting and undercutting of the backshore zone, massive faulting of the overhanging shoreline, and removal of the melting and slumping debris. At erosion monitoring sites in fine-grained frozen silts and clays, representative of over three-quarters of the postimpoundment shoreline, rates of retreat of up to 12 m/yr were measured. The index of erosion based on the wave energy impinging on the shoreline was 0.00035 sq m/tonne. After 5 years of erosion, restabilization of the shoreline has occurred only where bedrock has been encountered on the retreating backshore. Clearing of the forested backshore prior to flooding did not affect the erosion rates. The rapidly eroding shorelines have increased the suspended sediment concentration in Southern Indian Lake water and have triggered degradation of the commercial fishery.

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Newbury, R.W., McCullough, G.K. and Hecky, R.E., 1984. "The Southern Indian Lake Impoundment and Churchill River Diversion." Can. J. Fish. Aquat. Sci. 41:548-557. (46)

The 242 000-km^2 Churchill River basin extends across the northern half of Alberta, Saskatchewan, and Manitoba. In 1976, hydraulic control structures were completed to divert 75% of the natural river flow of 958 m^3/s across the drainage divide separating the Churchill and Nelson river basins in northern Manitoba. The diversion flows follow 300 km of tributary valleys southward to the Nelson River

channel where a 30-yr, 10 000 MW hydroelectric scheme is being developed. The diversion was accomplished by damming the northern outlet of Southern Indian Lake. The dam caused flooding of 414 km^2 of the backshore zone. Permafrost, or permanently frozen ground, is widespread in the uplands surrounding the lake. As bedrock occurred on only 14% of the post-impoundment shoreline, severe erosion of the frozen backshore deposits is now underway. A long period of instability is anticipated on lake shorelines and in river valleys affected by the altered hydraulic regime. Although the whole-lake water exchange time was increased by only 41% by the impoundment, the circulation patterns and exchange times in individual basins of the lake were changed dramatically when the Churchill waters were diverted at the southern end of the lake. The effects of the changing regimes on the aquatic habitats and fisheries of Southern Indian Lake have been investigated in pre- and post- impoundment studies undertaken by the Freshwater Institute of the federal Department of Fisheries and Oceans.

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Newbury, R.W. and McLeod, S.L., 1973. "Environmental Impact Assessment Methodology and Techniques for Assessing the Impact of the Churchill River Diversions" in "Proc. Nat. Conf. E.I.A.: Philosophy-Methodology". Aqassiz Center for Water Studies, Winnipeg, Man. (11) 188-207. (47)

The evaluation of physical impact in the environment is now widely addressed in North America. Governments and interest groups agree that in the 1970's the effects of major economic developments should not be undertaken without consideration of the long term environmental consequences, potential alternatives, and compensating benefits. This paper examines the development of the data set, that describes to the best of scientific capabilities the effects anticipated. Involved in the preparation of a data set for impact assessment are three major rules, inventory statement, impact assessment statement, and impact statement. The Churchill River Diversion impact study is used as an example. (3 References, 16 Figures, 2 Tables).

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Noton, L.R. and N.R. Chymko, 1977 "Water Quality and Aquatic Resources of the BeaverCreek Diversion System". Syncrude Env. Res. Mono. 1978-3. (48)

The Beaver Creek Diversion System was investigated from March to November, 1977, to describe post-diversion conditions in Beaver Creek, Ruth Lake and Poplar Creek and to characterize the two newly created

water bodies in the system. Ten sites in the system were sampled regularly for physical-chemical parameters, phytoplankton, zooplankton and benthic macroinvertebrates. Additional surveys were done for fish, aquatic macrophytes, stream drift and stream habitat. Results are discussed in some detail.

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Patalas, K. and Salki, A., 1984. "Effects of Impoundment and Diversion on the Crustacean Plankton of South Indian Lake." Can. J. Fish. Aquat. Sci. 41:613-627. (49)

Planktonic crustaceans in Southern Indian Lake were surveyed in 1972 before impoundment, during 1975 when water levels rose above the recorded high level, and then annually from 1977 to 1980 after full impoundment and diversion. Synoptic data were collected in each of these years in midsummer during July or August from a set of 53 stations covering all regions of the lake. Vertical hauls were made at each station using twin nets. In 1972, the crustacean plankton fauna of Southern Indian Lake was composed mainly of 15 copepod and 15 cladoceran species. At least 25 of these species were truly pelagic, while 5 were littoral. Following diversion in 1976, no dramatic changes in species composition were observed. However, the mean abundance of crustaceans decreased during the period 1977-80. Regional zooplankton responses were varied, but no significant changes occurred in areas adjacent to the Churchill River inflow. In the main water bodies north of the diversion route, abundances declined by 60% and biomass by 50%. A 2-3^{o}C drop in northern basin water temperatures, related to diversion, reduced growth rates by approximately 20% and resulted in a 60% decline in crustacean production. Not all groups of crustaceans responded similarily to impoundment and diversion. Reductions were related to decreased water temperatures, lower midsummer chlorophyll a concentrations, and decreased water transparencies. The mean abundance of calanoids as a group did not change, but the abundance and distribution of individual species were variably altered. Smaller calanoid species showed either no change or a decrease in their numbers and distribution. Larger species, were significantly more abundant and widespread following diversion. These large species, preferred food items for both whitefish and cisco, are cold stenotherms, inhabiting deeper water layers. Their increased abundance is likely associated with decreased water transparency offering better protection against predatory fish, decreased water temperature creating more favourable conditions, and increased water depth enlarging the volume of deeper water suitable for these species.

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Peet, S.E. and Day J.C., 1980. "The Long Lake Diversion: An Environmental Evaluation." Can. Wat. Res. J. 5(3): 34-48. (50)

The Long Lake Diversion was completed in 1939 in northern Ontario Precambrian Shield topography. It redirects the northward flowing Kenogami River south to Lake Superior. Major goals of the scheme were to provide water for local and Great Lakes area hydroelectric generation and to facilitate interbasin pulpwood transportation. The study evaluates direct and biophysically induced socio-economic effects of the diversion. Flow regulation and log handling impacts are examined in downstream, receiving water-body, diversion channel, and reservoir areas. Prediversion environmental conditions are established to ascertain created, residual, and foregone resource opportunities. A survey of resource managers' and diverted watershed residents' perceptions and attitudes concerning the scheme and a project benefit-cost analysis are undertaken. The study reveals that following project completion there was a period of ecological and social disruption followed by adjustment and relative stability. But in general, project-induced problems have been minor compared to overall benefits during the project life.

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Prinsenberg, S.J., 1980. "Man-Made Changes in Freshwater Input Rates of Hudson and James Bays." Can. J. Fish. Aquat. Sci. 37:1101-1110. (51)

The freshwater input rates of the Hudson/James Bay region were obtained on a monthly time scale and include contributions of evaporation, precipitation, and river runoff. The yearly mean precipitation minus evaporation rate shows that it behaves as an oceanic region supplying the overlying air mass with moisture. The monthly runoff rates for the total region and James Bay alone have minimum values during the winter and maximum values during the spring freshet. The total freshwater input can be divided into a winter and summer season. The large input of the summer represents an average monthly addition of a 10.0-cm layer of fresh water while the smaller winter input amounts to addition of a 0.5-cm layer of fresh water. Annually, the total surface area receives a layer of 64 cm of fresh water.

During the 1980s, four hydroelectric developments will cause temporal changes in the freshwater input cycle as winter river runoff rates will increase to values comparable to spring peak runoffs. In the Nelson-Churchill River development, the Churchill River runoff will be reduced to 29% of its natural state during the winter and to 54% during the summer. This water will increase the runoff into the Nelson River Delta by 52% in the winter and 10% in the summer. Similarly, the Eastmain River runoff will be reduced by 79%. The La Grande River will

double its yearly averaged runoff rate and experience a 500% increase in runoff during the winter. The other two developments, Nottaway-Broadback-Rupert rivers (N.B.R.) and Great Whale-Little Whale proposals, will experience similar changes: large increases in the winter runoff rates and small decreases in summer rates.

The total fresh water input into James Bay will be doubled during the winter months. In addition, half the future input will occur in the northern region which now receives only 20%. The La Grande River winter runoff rate will equal in magnitude that of the Nelson River Delta which presently accounts for 25% of the Hudson/James Bay winter runoff. The runoff for the total Hudson/James Bay region will also experience the largest changes during the winter when the average monthly runoff rate will increase by 52%, due largely to the La Grande Complex. On the other hand, the summer runoff rate for the total region will decrease by 6%.

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Quinn, F., 1981. "Water Transfers - Canadian Style". Can. Wat. Res. J. 6(1): 64-75. (52)

A descriptive overview is presented of water transfers existing and under construction in Canada. The ease of connecting proximate watercourses is attributed to recent glacial history. Criteria for establishing a national inventory of water transfers are identified.

Tentative findings focus on the number, location, size, use, operational date and ownership of transfer projects across the country; the largest transfers are highlighted. It is believed that Canadian water transfer is of a scale and character unknown in any other country.

Alberta's interest in southward diversion to favor consumptive uses in the province is portrayed as an exception to the hydro-dominated national transfer pattern and as a source of concern to downstream jurisdictions.

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Seagel, G.C. and Pugh, M.F., 1980. "A Perspective on Water Transfer: McGregor Diversion Project". Reid Crowther & Partners Limited, (Presented at Canadian Water Resources Association Conference, 1980). (53)

Using their experience on the McGregor Diversion Project in British Columbia the authors provide a perspective on environmental concerns of water transfer.

The paper discusses some aspects of water transfer associated with the McGregor Diversion Project, discussing principal factors which make such schemes unique from other water management projects. Specifically, the paper deals with the faunal transfer question in terms of a donor stream, diversion structures and receiving streams. The paper concludes that study of faunal transfer should be undertaken for all water transfer projects. However, such studies should be reviewed in the context of the assessed values of the resources which might possibly be affected; and in terms of multiple use of the waters.

The authors point to limiting and deciding factors which can affect the decision rationale in faunal transfer studies; the importance of understanding the human values associated with such projects; and the lack of precedent for such studies and associated study rationale.

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Soucy, A., 1978. "James Bay Hydroelectric Development: Evolution of Environmental Considerations." Can. Wat. Res. J. 3(4): 54-88. (54)

After giving a brief history of the James Bay hydro-electric development project, the manager of the environment department shows how environmental considerations have evolved as the construction of the La Grande Complex progressed. This evolution owes a lot to the important changes that have occurred in Canada and Quebec in the field of environmental protection since the beginning of the seventies and since the launching of the project.

During the first phase of the project, efforts were focussed on acquiring a thorough knowledge of the ecology of the territory and on settling native land claims through negotiations which led to the signing, in November 1975, of the James Bay and Northern Quebec Agreement by all parties concerned.

Although the social impacts of the project have been a major preoccupation, numerous environmental studies were carried out in order to optimize engineering alternatives and minimize the biophysical impacts of the different works required to harness rivers.

For almost all the components of the La Grande Complex, several recommendations were submitted by the environment department at the preliminary stage of a project as well as at the final drafting of the tender document. In a project of such magnitude, it is indeed important to apply a day-to-day control in order to efficiently take environmental considerations into account in the management process. During the construction phase, a special monitoring network was set up to insure a better protection of the environment. Specific environmental provisions designed to complement government rules and regula-

tions were adopted to the Societe d'energie de la Baie James (SEBJ), which integrates them into all its contracts. An officer working on each job site reports directly to the job site manager and is responsible for the application of these regulations and for the overall protection of the environment. Things have changed since the opening of the first job site; today, more than 14,000 people are working on five important job sites.

Efforts are presently concentrated on defining remedial works to be undertaken, such remedial works being associated with reservoirs, construction sites and diversion areas. Moreover, two organizations, created under the provisions of the James Bay and Northern Quebec Agreement and including native representation, were mandated to determine the measures that can most likely encourage native people to carry on their traditional hunting, fishing and trapping activities.

Finally, SEBJ's environment department has recommended the establishment of an important ecological monitoring program designed to scientifically evaluate the behavior of the various environments prior to and after the filling of the reservoirs. The results of these studies allow a better management of the works, serve as guidelines in determining the remedial measures to be taken and help in predicting the effects of future developments with greater reliability.

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Stewart, K.W.; Suthers, I.M.; and Leawesley, K. New Fish Distribution Records in Manitoba and the Role of a Man-Made Interconnection Between Drainages as an Avenue of Dispersal University of Manitoba, Department of Zoology, 20 p. (55)

The first record of Pomoxis annularis in Manitoba and range extensions within Manitoba for Umbra limi, Notropis dorsalis, Notropis heterodon, Carpiodes cyprinus, Ictiobus cyprinellus, Moxostoma macrolepidotum, Ictalurus melas, Noturus flavus, Noturus gyrinus, Fundulus diaphanus, and Morone chrysops are presented and discussed. Notropis heterodon and N. dorsalis probably were overlooked or misidentified previously, while all the other species seem to represent a combination of real extensions of range, increases in abundance where found, and/or recent increases in collecting effort. The opening of the Assiniboine River Floodway has provided an access route for Umbra limi, Ictiobus cyprinellus, Ictalurus melas, Noturus gyrinus and probably Ictalurus punctatus. to reach southern lake Manitoba.

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Tutty, B.D., 1979. "1977 Chinook Salmon Investigations Associated with the McGregor River Diversion". Fisheries and Marine Service, Dept. of Fisheries & Oceans. (56)

Diversion of the McGregor River flow from the Pacific draining into the Arctic drainage has been considered for power generation and flood control by B.C. Hydro and Power Authority. Investigations to determine the environmental impacts of this scheme were conducted in 1976-77. A mainstem spawning race of Chinook was recorded for the first time. Preliminary investigations indicate significant Chinook production may result from the overwintering subpopulations that were captured in May. In 1979, B.C. Hydro publicly advised postponement of the project due to the possibility of transferring Chinook salmon parasites to Arctic fish species. This action was precipitated largely by the discovery of the fish Pathogen Certomyxa shasta in spawning Chinook specimens.

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Walburg, C.H., Novotny, J.F., Jacobs, K.E., Swink, W.D., Campbell, T.M., Nestler, J. and Saul, G.E., 1981. "Effects of Reservoir Releases on Tailwater Ecology: A Literature Review". Technical Report E-81-12, U.S. Dept. of the Interior, FWS. 188 pp. (57)

This document presents a review of the often contradictory literature describing the effects of release waters on the tailwater environment and biota. The physical and chemical condition found in tailwaters downstream from warm water and cold water discharge impoundments are compared and contrasted to those found in natural streams.

Reservoir discharges modify the physical, chemical, and biological characteristics of the stream ecosystem. Physical and chemical characteristics in tailwaters are primarily determined by the depth, volume, and schedule of water releases. The magnitude of change is related to the type of reservoir and to the design and operation of outlet structure.

The structure of the biotic community reflects the physical and chemical conditions existing in a particular tailwater. The community is composed of organisms, including nonnative species, that are adapted to this environment. The effects of the tailwater environment on the life history, physiology, and abundance of selected species are described.

This information will aid in the development of reservoir discharge guidelines that will enhance the quality of the tailwater environment to increase project benefits.

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Wiens, A.P. and Rosenberg, D.M., 1984. "Effect of Impoundment and River Diversion on Profundal Macrobenthos of Southern Indian Lake, Manitoba." Can. J. Aquat. Sci. 41:638-648. (58)

Profundal macrobenthos in Southern Indian Lake, Manitoba, were surveyed to determine effects of hydroelectric manipulations in 1972 (pre- impoundment), 1977 (post- impoundment), and 1979 (post-diversion). Lakewide average standing crops increased following impoundment and decreased by 3 yr after impoundment. Regional changes in standing crops usually could be related to additions of nutrients leached from flooded vegetation, additions of particulate organic matter resulting from shoreline erosion, and changes in integral primary production and suspended solids concentrations before and after impoundment. Greater increases in standing crops of macrobenthos in shallower compared with deeper depth zones of the lake after flooding were attributed to preferential deposition of organic materials in the shallow areas of the lake. Mean standing crops of macrobenthos were higher in regions through which the Churchill River flowed than in regions isolated from the flow before and after impoundment. After diversion, greatest decreases in standing crops occurred in isolated regions, whereas those of regions in the flow declined much less or increased. Responses of the most abundant taxa of macrobenthos differed in many ways from those recorded for other new reservoirs. Pontoporeia brevicornis remained the most abundant benthic organism, there was no evident succession of macrobenthic taxa, and a high diversity of profundal species was maintained. These results, together with the slight changes in standing crop observed after flooding, indicated only a marginal impact on macrobenthos caused by the low-level flooding of Southern Indian Lake.

6.0 APPENDICES

6.1 Date Base Descriptions

6.1.1 CAN/OLE

- **BioSciences Information Services (BIOSIS) Previews**

BIOSIS Previews provide worldwide coverage of literature in the life sciences. The databases include items concerned with the study of living things, their applications, environment, identification and processes. Interdisciplinary areas such as biochemistry, biomedecine, instrumentation and pharmacology are also covered. Over 9,000 journals are monitored along with monographs, conference proceedings, theses, reports, reviews and letters.

Abstracts

available (1982-)

Printed equivalents
Biological Abstracts
Biological Abstracts/RRM (formerly BioResearch Index)
BioResearch Index

Publisher

BioSciences Information Service
2100 Arch Street
Philadelphia, Pennsylvania 19103
USA

Coverage

BA: 1969-1971
BA72: 1972-1978
BA79: 1979-present
Updates - 26,000 references monthly

Size

BA: 680,000 references
BA72: 1,712,000 references
BA79: 1.537,000 references

CAN/SDI

Centre - CISTI
Frequency - 48 issues annually

Aquatic Sciences and Fisheries Abstracts (ASFA)

ASFA is an international database covering all aspects of marine biology and ocean technology, including aquatic organisms and their environment (including pollution), coastal zone management, fish products, geophysics and geochemistry, law of the sea, limnology, marine resources such as gas and oil, natural resources (particularly fisheries), ocean policy and physical and chemical oceanography. Over 5,000 journals are monitored as well as monographs, conference proceedings, government and technical reports and theses.

Abstracts

available

Printed equivalents

ASFA 1, Biological Sciences and Living Resources
ASFA 2, Ocean Technology Policy and Non-Living Resources

Publisher

Cambridge Scientific Abstracts
5161 River Road
Bethesda, Maryland 20816
USA
Under contract to the Foods and Agriculture Organization of the United Nations, Rome.

Coverage

1978-present
Updates - 2,000 references monthly
Size - 150,000 references

CAN/SDI

Centre - CISTI
Frequency - 12 issuses annually

IEC, Directory of Federally Supported Research in Universities

The IEC database is a compilation of Canadian university based research projects as reported to the Information Exchange Centre at CISTI by granting agencies of the federal government.

Also included are contracts to Canadian universities awarded by Supply and Services Canada on behalf of various federal government departments.

Abstracts

not available

Printed equivalent
Directory of Federally Supported Research in Universities

Publisher

Canada Institute for Scientific and Technical Information
National Research Council Canada
Ottawa, Ontario K1A 0S2

Coverage
fiscal year 1971/72-present
Updates - 10,000 references annually
Size - 121,100 research projects

CAN/SDI

not available

Environment Libraries Automated System (ELIAS)

The ELIAS database corresponds to the holdings of 15 libraries participating in the Environment Canada Departmental Library network; also included is a collection from Fisheries and Oceans Canada. The collections include serials, monographs, conference proceedings and technical reports.

Abstracts

not available

Printed equivalent
none

Publisher

Environment Canada
Departmental Library
Place Vincent Massey
Ottawa, Ontario
K1A 0C7

CAN/OLE

Coverage - 1976-present

Updates - 400 references monthly
Size - 32,400 references

CAN/SDI

not available

6.1.2 Quicklaw Systems (QL)

- Canadian Environment (CENV)

CENV provides comprehensive coverage of scientific and technical literature, together with general interest articles pertaining to the Canadian Environment. Major fields covered, include: water (every aspect), wildlife, land, fisheries, and baseline studies.

Conference proceedings and over 200 Canadian and foreign journals are monitored plus reports and publications of Environment Canada, other federal, provincial, and municipal government departments and agencies, universities, and research establishments.

Note: This data base is now available on the CAN/OLE system as data base AQUAREF.

Abstracts

available (1970-present)

Printed Equivalent

none

Publisher

WATDOC
Inland Waters Directorate
Environment Canada
Ottawa, Ontario
K1A 0E7
Tel: (819) 997-1238

Coverage

1970 - present
Updated - bi-monthly
Size - 47,000 references

Canadian Plains Research (CPL)

The Canadian Plains Research Inventory is a comprehensive collection of current, recently completed, and unpublished research projects for the three Canadian prairie provinces, Manitoba, Saskatchewan, and Alberta.

The data base covers the period 1975 to the present with some masters and doctorate theses dating back to 1920. All subjects are covered, with emphasis on education, the environment, agriculture, and criminology.

Abstracts

Titles and brief descriptions of research projects. Anyone wishing additional information concerning any of the documents should contact the persons indicated in the documents.

Printed Equivalents

none

Producer

Canadian Plains Research Centre
University of Regina

Data Reference (DREF)

References to Canadian data collections and data handling systems in the field of lands, forestry, wildlife, water resources and other related topics.

Data collections and data handling systems of the Environmental Conservation Service, Environment Canada are inventoried, together with relevant data collection and systems in other federal and provincial government agencies, universities, and private organizations. Data collections may be either in hard copy form (publication), or in machine readable form.

Producer

WATDOC
Inland Waters Directorate
Environment Canada
Ottawa, Ontario
K1A 0E7

Coverage

Includes data collections dating back to the early 1900's, to present.
Size - over 800 references

6.2 Response Cards

Name: _____ Address: _____

Position: _____ _____

Telephone: _____

Please check the appropriate box(es) and return.

☐ We have no information concerning environmental effects of existing water diversions.

☐ Information requested will be forthcoming.

☐ A copy of your request has been forwarded to: _____

_____

_____

Figure 3: Questionnaire Card

Name: _____ **Address:** _____

Position: _____ _____

Telephone: _____ _____

Please check the appropriate box(es) and return.

☐ **Reports/articles requested will be forthcoming.**

☐ **Information requested is no longer available.**

Figure 4: Follow-up Card

6.3 Contacts Directory

6.3.1 Consultants

Beak Consultants Ltd. 1550 Alberni Vancouver, British Columbia V6G 2X5	684-8361
Entech Environmental Consultants Ltd. 3 - 566 Cardero Vancouver, British Columbia V6G 2W6	688-7221
IEC International Environmental Consultants Ltd. 202 - 5600 Caderbridge Way Road Vancouver, British Columbia V6X 2A7	273-0151
Paish Howard & Associates Ltd. 1102 Grover Avenue Coquitlam, British Columbia V3J 3G1	299-8531
Tera Environmental Resource Analysts Ltd. 102 - 3309 Dunbar Vancouver Vancouver, British Columbia V6S 2B9	224-4371
ID Systems Ltd. 107 - 5240 Calgary Trail Edmonton, Alberta T6H 5G8	434-1372
Norecal Ltd. 10509 81 Avenue Edmonton, Alberta T6E 1X7	439-3865
Envirocon Ltd 2021 41 Avenue N.E. Calgary, Alberta T2E 6P2	276-4474
Reid Crowther & Partners Ltd. 7410 Blackfoot Tr. S.E. Calgary, Alberta	253-3301

Hardy Associates Ltd.
221 18 Street S.E.
Calgary, Alberta
T2E 6J5 — 248-4431

MacLaren Plansearch Services Ltd.
610 - 224 4th Avenue S.
Saskatoon, Saskatchewan
S7K 5M5 — 652-0557

Systems Evaluation & Resource Assessment
175 Bluewater, St. Boniface
Winnipeg, Manitoba
R2T 2X6 — 257-4588

6.3.2 Federal and Provincial Government

British Columbia

Environmental Biologist or Librarian
Inland Waters Directorate
1001 West Pender Street
Vancouver, British Columbia
V6E 2M9 — Federal

National Water Research Institute
4160 Marine W. Vancouver
Vancouver, British Columbia
V7V 1N6 — Federal

Department of Environment
Water Management Branch
10334 152 A Street
Surrey, British Columbia
V3R 7P8 — Provincial

Mr. Robert Stone
Environmental Assessment Division
11th Floor, Oxbridge Place
9820 - 106th Street
Edmonton, Alberta
T5K 2J6 — 427-6339 Provincial

Environmental Council of Alberta
8th Floor Weber Centre
5555 Calgary Trail Southbound N.W.
Edmonton, Alberta
T6H 5P9 — Provincial Director of Research 427-5803

Water Quality Branch
Inland Waters Directorate,
District Office
725 11th Avenue S.W.
Calgary, Alberta
T2R 0E3

231-5619
Federal

Manitoba

Environmental Assessment & Review Agency
139 Tuxedo Avenue
Building 2
Winnipeg, Manitoba
R3N 0H6

944-7090
Provincial

Environmental Management Division
139 Tuxedo, Box 7
Building 2
Winnipeg, Manitoba
R3N 0H6

944-7074
Provincial

Ontario

Environmental Biologist or Librarian (Ottawa)
Inland Waters Directorate
Place Vincent Massey,
351 St. Joseph Blvd.
Hull, Quebec
K1A 0E7

997-2639
Federal

Environmental Biologist
Canada Centre for Inland Waters
867 Lakeshore Rd., P.O. Box 5050
Burlington, Ontario
L7R 4A6

637-4531
Federal

National Water Research Institute
867 Lakeshore, P.O. Box 5050
Burlington, Ontario
L7R 4A6

637-4303

Environmental Assessment Board
5th Floor, St. Clair Ave. West
Toronto, Ontario
M4V 1K7

Water Resources Branch
1 St. Clair Avenue West
Toronto, Ontario
M4V 1K6

Quebec

Water Quality Division
Inland Waters Directorate
1001 Pierre Dupuy
Longueuil, Quebec
T4K 1A1
283-3916
Federal

Environmental Biologist or Librarian
Inland Waters Directorate
1141 route de L'Eglise, 8e ètage
Sainte-Foy, Quebec
G1V 4H5
Federal

Mr. Robert Tètreault
Assainissement de l'eau
5199, rue Sherbrooke est
Montreal, Quebec
H1T 3X9
Provincial

New Brunswick

Dr. Louis Laprierre
Environment Council
P.O. Box 6000
Fredricton, New Brunswick
E3B 5H1
Provincial

Water Survey of Canada
Inland Waters Directorate
633 Queen Street
Fredricton, New Brunswick
E3B 1C3
452-3095
Federal

Nova Scotia

Environmental Assessment Division
Department of Environment
Centennial Building, 6th Floor
P.O. Box 2107
Halifax, Nova Scotia
B3J 3B7
424-5300
Provincial

Environmental Biologist or Librarian
Inland Waters Directorate
45 Alderney Drive
Dartmouth, Nova Scotia
B2Y 2N6
Federal

Prince Edward Island

Water Resources Branch
Inland Waters Directorate
P.O. Box 2529
Charlottetown, P.E.I.
C1A 8C2

566-7062
Federal

Environmental Services
3 Queen Street
Charlottetown, P.E.I.
C1A 2P6

892-9174
Provincial

6.3.3 Universities

Department of Biology
Acadia University
Wolfville, Nova Scotia
B0P 1X0

Mr. F.S. Chia
Department of Zoology
University of Alberta
Edmonton, Alberta
T6G 2E2

Chairman, Biology Program
Faculty of Science
Biological Sciences Building,
Room 1507
University of British Columbia
Vancouver, British Columbia
V6T 1W5

Mr. R.K.J. Van Hulst
Department of Biological Sciences
Bishops University
Lennoxville, Quebec
T1M 1Z7

Mr. M.S. Manocha
Department of Biological Sciences
Brock University
St. Catharines, Ontario
L2S 3A1

Department of Zoology
Faculty of Science
Brandon University
Brandon, Manitoba
R7A 6A9

Mr. R.W. Davies
Department of Biology
University of Calgary
2500 University Drive N.W.
Calgary, Alberta
T2N 1N4

Mr. D.R. Gardiner
Dept. of Biology, Faculty of Science
Carleton University
Colonel By Drive
Ottawa, Ontario
K1S 5B6

Mr. James Foulds
Department of Biology
Faculty of Math & Natural Sciences
University College of Cape Breton
Sydney, Cape Breton, Nova Scotia
B1P 6L2

Mr. B.K. Hall
Department of Biology
Faculty of Arts & Sciences
Dalhousie University
Halifax, Nova Scotia
B3H 4H6

Mr. R.C. Anderson
Department of Zoology
College of Biological Science
Guelph University
Guelph, Ontario
N1G 2W1

Mr. A.D. MacDonald
Department of Biology
Lakehead University
Thunder Bay, Ontario

Mr. W. Leggett
Department of Biology
Stewart Biology Building
1205 Avenue Docteur Penfield
Montreal, Quebec
H3A 1B1

Mr. D.T. Canvin
Department of Biology
Earl Hall, Room 206
Faculty of Arts & Science
Queen's University
Kingston, Ontario
K7Z 3N6

Mr. R.A. Liversage
Department of Zoology,
St. George Campus
Faculty of Arts & Science
University of Toronto
315 Bloor Street West
Toronto, Ontario
M5S 1S5

Mr. Ninian N. Leblanc
Faculty of Biology
University of Prince Edward Island
Charlottetown, Prince Edward Island
C1A 4P3

Mr. E.K. Winterhalder
Department of Biology
Laurentian University
Ramsey Lake Road
Sudbury, Ontario
P3E 2C6

Mr. J.H. Gee
Department of Zoology
Faculty of Science
University of Manitoba
Winnipeg, Manitoba
R3T 2N2

Mr. D.B. Burt
Department of Biology,
Faculty of Science
University of New Brunswick
College Hill, Box 4400
Fredricton, New Brunswick
E3B 5A3

Mr. K.K. Nair
Department of Biological Sciences
Shrum Science Centre B8255
Simon Fraser University
Burnaby, British Columbia
V5A 1S6

Mr. W.B. Mitchell
Faculty of Environmental Studies
University of Waterloo
Waterloo, Ontario
N2L 3G1

Mr. R.M. Agnew
Department of Biology
Faculty of Science
University of Regina
Regina, Saskatchewan
S4S 0A2

Mr. J. King
Department of Biology
Faculty of Arts & Science
University of Saskatchewan
Saskatoon, Saskatchewan
S7N OWO

Mr. Edward E. Spence
Faculty of Environmental Studies
Room 552, Scott Library,
York University
4700 Keele Street
Downsview, Ontario
M3J 2R2

Dr. J.C. Day
Natural Resources Management Program
Simon Fraser University
Burnaby, British Columbia

Head of Department
Department of Biology,
Faculty of Science
University of Western Ontario
London, Ontario
N6A 3K7

Department of Biology
Faculty of Science
University of Windsor
Windsor, Ontario
N9B 3P4